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Physical/Chemical Treatment of Textile Finishing Wastewater for Process Reuse

J. P. Stevens and Co, Greensboro, N C

Prepared for

Industrial Environmental Research Lab, Research Triangle Park, N C

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PHYSICAL/CHEMICAL TREATMENT OF TEXTILE FINISHING WASTEWATER FOR PROCESS REUSE

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16. ABSTRACT

The report describes a demonstration of multimedia filtration as an effective tertiary treatment for biologically treated textile wastewaters from two adjacent plants involved in dyeing and finishing fabrics of man-made fibers. Adding alum, polyelectrolytes, and powdered activated carbon to the treated wastewater, just ahead of multimedia filtration, reduced criteria pollutants and produced effluent meeting NPDES requirements. Treated wastewater was further treated to provide colorless effluent satisfactory for reuse in dyeing man-made fibers in a pilot plant consisting of a coagulation/settling/filtration unit followed by a five-column train comprised of a sand filter, organic scavenging resin, granular activated carbon, and cation and anion exchange resins. This water was satisfactory for dyeing a full range of shades, including white and pastel colors on man-made fiber fabrics. Colorfastness was equivalent to that of standard control dyeings. Tramp color scavenging ability of different man-made fibers was found to be quite variable. Essentially colorless effluent is required for reuse in dyeing white or pastel shades on nylon and triacetate fabrics. Although technical feasibility of further treating biologically treated effluent to permit its use in critical dyeing and finishing operations was demonstrated, the economics of commercial application are not attractive.

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Textile Finishing	Decoloring	Biological Treatment	13H	
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by

J.M. Eaddy, Jr. and J.W. Vann

J.P. Stevens and Company
P.O. Box 21247
Greensboro, North Carolina 27420

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Industrial Environmental Research Laboratory
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Research Triangle Park, NC 27711

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ABSTRACT

The effectiveness of multimedia filtration has been demonstrated as a reliable means of tertiary treatment of biologically treated wastewaters from two adjacent plants involved in dyeing and finishing fabrics of man-made fibers. Chemical additions of alum, polyelectrolytes, and powdered activated carbon to the waste stream ahead of multimedia filters effected additional pollutant and color removals which were required to produce an effluent quality satisfactory to meet National Pollutant Discharge Elimination System requirements.

A pilot wastewater treatment plant, comprised of a 10 gpm coagulation/settling/filtration unit followed by a 1.5 gpm 5-column train comprised of sand filter, organic scavenging resin, granular active carbon, cation exchange resin and anion exchange resin was employed to provide an essentially colorless effluent suitable for dyeing nylon, polyester, acetate and triacetate fibers. Tramp color scavenging ability of four fibers in fabric form was determined. Nylon and triacetate were essentially equal in extremely high color scavenging ability, while acetate and polyester fibers exhibited a much lower color scavenging ability.

Relative whiteness determinations showed that an essentially colorless effluent was needed to consistently dye white and pastel shades on nylon and triacetate fabrics. Colorfastness of the fabrics dyed with water from the pilot plant was equal to that of control dyeings.

This report was submitted in fulfillment of Grant Number S801211 by J.P. Stevens & Company, Inc. under the partial sponsorship of the U. S. Environmental Protection Agency. This report covers an EPA grant period from March 1, 1973 to February 28, 1978. The work was completed as of May 31, 1977.

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ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

Avg., Ave.	--average
BOD_5	--five-day Biochemical Oxygen Demand
COD	--Chemical Oxygen Demand
Cu. Ft.	--Cubic Feet
Ft.	--Feet
FTU	--Formazin Turbidity Units
GPSFPD	--Gallons per square foot per day
GPD	--Gallons Per Day
GPM, gpm	--Gallons Per Minute
GPM/sq. ft.	--Gallons per Minute Per Square Foot
Hp	--Horse power
I.D.	--Inside Diameter
JTU	--Jackson Turbidity Units
Lbs.	--Pounds
Lbs/Day	--Pounds Per Day
MGD	--Million Gallons Per Day
MG/L, mg/l	--Milligrams per Liter
ml	--Milliliters
mm	--Millimeters
MPP	--Mobile Pilot Plant (Coagulation/Settling/Filtration Unit)
N	--Normality
nm	--nanometers
No.	--number
PAC	--Powdered Activated Carbon
pH	--Logarithm (base 10) of the inverse of the hydrogen ion concentration. Measure of the acidity or alkalinity of an aqueous solution.

ABBREVIATIONS (Continued)

PPM, ppm --Parts per Million
Psi --Pounds per square inch
Pt-Co Units --Platinum-Cobalt units of color
RPM --Revolutions Per Minute
TOC --Total Organic Carbon
ug/l --Micrograms per liter
u.c. --Uniformity coefficient
umhos --Micromhos

SYMBOLS

@ --at
°C --Degrees Celsius
°F --Degrees Fahrenheit
2° --Secondary
' --Foot (12 inches)
" --Inches
< --Less than
> --More than
% --Percent

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SECTION 1

INTRODUCTION

The J. P. Stevens and Company, Inc. facilities located in Wallace, N.C. consist of two manufacturing plants. These plants produce primarily dyed and finished man-made tricot and doubleknit fabrics. Each of these manufacturing facilities discharge to a common wastewater treatment facility. This wastewater treatment system, immediately prior to installation of the advanced wastewater treatment system, consisted of mixing/equalization, extended aeration activated sludge, clarification and post-chlorination. The biological sludge was aerobically digested, thickened, dried on sand beds and disposed of by land-filling.

A continuing program of stream improvement, including reclassification and upgrading by the State of North Carolina, and the establishment of the National Pollutant Discharge Elimination System (NPDES) required a higher quality effluent and, therefore, more stringent treatment than could be gained from secondary biological treatment followed by chlorination and post-aeration. The requirements for the Wallace, N. C. facilities are a maximum (30-day average) BOD_5 and suspended solids concentration of 5 mg/l for each, and a final effluent dissolved oxygen (D.O.) concentration of 5 mg/l.

A number of treatment systems were considered. The J. P. Stevens and Co., Inc. personnel recognized that any system chosen would have a degree of risk associated with it as none had been applied full-scale in the textile industry. The successful application of multimedia filtration as an advanced wastewater treatment process in non-textile applications stimulated installation at Wallace, N. C. The four multimedia filtration units installed are capable of treating 5 million gallons per day (MGD).

As an effort to go beyond the NPDES requirements and considering possible future situations, the next logical step was the evaluation of water reuse within the production facility. A Research Demonstration grant was applied for from the U. S. Environmental Protection Agency (EPA) to demonstrate the degree of pollutant removal necessary to meet effluent treatment requirements which could be achieved with multimedia filtration. A second objective was to determine if the effluent from the multimedia filters could be further treated by additional, selected advanced wastewater treatment processes to a degree suitable to allow reuse within the dyeing and finishing operations.

SECTION 2

CONCLUSIONS

Full-scale multimedia filtration followed by pilot scale advanced treatment and subsequent reuse trials were evaluated at the Wallace, N. C. plants of J. P. Stevens and Co., Inc. The conclusions, based on these evaluations, are:

(1) Multimedia filtration with chemical pre-conditioning was demonstrated to be a viable means of meeting stringent effluent quality requirements for wastewater from two textile plants dyeing and finishing man-made fiber fabrics.

(2) Alum is a satisfactory primary coagulant for reducing suspended solids, BOD_5, COD, TOC, color and other parameters. Low concentrations of alum were needed and the efficiency of coagulation was improved when a compatible polyelectrolyte was added. Powdered activated carbon added under the same conditions reduced BOD_5 as well as color. The increased suspended solids volumes caused by the chemical additions created solids handling problems.

(3) Multimedia filter effluent treated by chemical coagulation, settling and filtration followed by treatment through a 5-column train (sand filter, organic scavenging resin, granular activated carbon, cation exchange resin and anion exchange resin) produced an essentially colorless effluent. This water was found satisfactory for dyeing a full shade range of shades including white and pastels on man-made fabrics of nylon, polyester, acetate and triacetate.

(4) Nylon and triacetate scavenged residual color very efficiently from the effluent from the 5-column train. Conversely, polyester and secondary acetate were found to be much less efficient color scavengers.

(5) The colorfastness of all four fibers dyed with selected dyes and wastewater treated through the entire treatment sequence, compared favorably with dyes and fibers processed in the normal manner.

(6) A serious problem of backwash water volume and treatment would result from a full-scale version of the Mobile Pilot Plant. A one million gallon-per-day version of this pilot plant was estimated to generate 235,000 gallons per day of backwash water at one regeneration for each unit each twenty-four hours. The backwash or wasting volume from each stage is estimated as follows: reactor/clarifier - 5,000 gpd; sand filter - 30,000 gpd; organic scavenging resin column 40,000 gpd; granular activated carbon column - 10,000 gpd; and 75,000 gpd each from the cation and anion exchange columns. Treatment for the backwash and or wasting flow would require more land, capital and equipment and new wastewater treatment problems would probably be introduced.

(7) Current operational and amortization costs for the biological and multimedia filter systems are 40¢ and 46¢ per thousand gallons, respectively. The treated process water costs, as supplied to the manufacturing plant is 41¢ per thousand gallons. Operating costs for the advanced waste treatment facility, as estimated by J. P. Stevens and Co., Inc. and presented in Section 9, is $1.06 per thousand gallons.

(8) Although the technical feasibility of further treating a biologically treated effluent to a quality sufficient to allow reuse in critical processing operations, e.g. dyeing and finishing, has been demonstrated, the economics of full-scale application are not satisfactory at the time of this investigation.

(9) The build-up of fine solid materials in the overall system, due to multimedia filtration, presents a major problem in achieving effluent total suspended solids values; particularly when effluent standards require extremely low concentrations.

SECTION 3

RECOMMENDATIONS

Full-scale multimedia filtration followed by pilot scale advanced treatment and subsequent re-use trials were evaluated at the Wallace, N. C. plants of J. P. Stevens and Co., Inc. The recommendations, based on these evaluations, are:

(1) Laboratory bench and pilot scale studies of treating textile dyeing and finishing wastewater indicated the need for relatively high concentrations of alum, polymer and powdered activated carbon, coupled with long coagulation and/or absorption times for successful treatment. Actual coagulation and/or absorption time between chemical additions and full-scale multimedia filtration in the plant was very short, in the range of six to fifteen seconds. Procedures for improving the coagulation reaction time should be investigated as a means of increasing the efficiency of pollutant removals in multimedia filtration.

(2) Color scavenging ability of nylon, polyester, acetate and triacetate have been investigated. This same investigation should be made on other fibers and blends of fibers.

(3) Textile plants considering water re-use would be well advised to segregate highly colored wastes to more effectively treat this lower volume at a lower overall cost per thousand gallons.

(4) Secondary clarifiers should be equipped with high turbidity alarms on the effluent outlet to give advanced warning of clarifier upset. This approach would greatly relieve the possibility of excessive suspended solids reaching the multimedia filters and permit bringing the wastewater treatment plant under control more rapidly in case of upset.

(5) Further investigation of available organic scavenging resins for their color removal efficiencies should be made.

(6) Continuous zeta potential readout and continuous monitoring of chemical feed volumes based on pre-determined amounts required to give desired level of treatment should be studied. Lower chemical costs and improved control over effluent quality should result.

(7) Available alternatives for eliminating/minimizing the problem of build-up of recirculated fine solid materials due to multimedia filtration in the overall system should be evaluated. This may involve side stream treatment by tertiary type treatment process, e.g., reverse osmosis.

SECTION 4

J. P. STEVENS MANUFACTURING FACILITIES

FIBERS AND CHEMICALS USED

J. P. Stevens and Co., Inc. has two manufacturing plants located in Wallace, N. C. One plant is engaged in the manufacture of warp knitted fabrics from various man-made fibers, which are subsequently dyed and finished. The other plant is solely a dyeing and finishing plant for circular knitted fabrics, mostly of 100% texturized polyester knits.

Both manufacturing plants have a maximum dyeing and finishing capacity of approximately 210,000 pounds per day. Average daily production is approximately 75 - 80% of that amount.

Dyeing and finishing by fiber type is as follows:

Fiber or Blend	Per cent of Total
100% Polyamide	27.9
100% Polyester	49.9
100% Acetate, secondary	11.1
80%/20% Acetate/Nylon	5.5
95%/5% Polyester/Nylon	2.9
80%/20% Triacetate/Nylon	2.7
	100.0

Dyeing is by the exhaustion technique using heat, pressure, acids and carriers, singly or in one of several combinations, to bring about exhaustion of the dyes from aqueous solution or dispersion onto and into the fiber substrate. The dye is 90% - 99% utilized, depending on dye class and application method; consequently a highly colored process water is discharged to the waste treatment system.

The types of dyeing procedures used include atmospheric and pressure beck dyeing, atmospheric and pressure beam dyeing, and high temperature jet dyeing. The dyes used are primarily of the disperse, acid, acid premetallized and naphthoic classes. Fluorescent brightening agents are also used in addition to a few basic and direct dyes.

Total dye consumption for both plants exceeds one million pounds per year. This consumption is further divided by dye class as follows:

Dye Class		Percent of Total
Disperse		80.25
Acid/Acid Premetallized		11.53
Fluorescent Brightener		5.33
Naphthoic (diazotized/developed)		2.73
Basic (Cationic)		0.12
Direct		0.04
	Total	100.00

A number of chemical auxilliaries are also used in the scouring and/or dyeing operations, which are sometimes carried out simultaneously. Control of pH is accomplished primarily by organic acids and organic and inorganic salts. A variety of surface active agents are employed which scour, level, complex and promote wetting, lubricity and dye migration.

Special operations for corrective procedures and/or dye fixation often require the use of chemicals which may cause problems in the waste treatment plant. The use of these chemicals is closely controlled to prevent effects in the treatment system, e.g. Mercury and Chromium compounds are not used. Some Copper and Antimony salts are required for very special dyeing applications. Color stripping sometimes requires use of a hydrosulfite or hypochlorite. Ammonia and organic nitrogen salts are sometimes used which add to the influent TKN. Inorganic nitrogen salts are also used in production. It should be noted, however, that virtually every dye used in these plants is a nitrogen containing dye which also contributes to a highly refractory (not easily biologically oxidized) TKN.

Carriers used to promote exhaustion of disperse dye into triacetate and polyester are of the ester and perchloroethylene types. There are no phenolics, such as orthophenylphenol, biphenyl or chlorinated aromatic carriers used. These have been replaced by the esters and perchloroethylene.

Finishing consists of the following processes, one or more of which is applied to all fabrics finished:

- Drying - remove moisture.
- Chemical finish application for aesthetic and/or functional reasons.
- Face finishing - via Schreiner calendering, napping, suedeing, shearing.
- Fix width and length to obtain fabric yield.
- Heat set thermosetting fibers to impart added dimensional stability and resistance to changes during laundering or dry cleaning.

The chemical additives applied for aesthetics purposes are normally softeners of the cationic and nonionic group, plus polyvinyl acetate and methacrylate resins for "hand" (texture) improvement. Combinations of aesthetic and functional finishes are used for special applications such as provided lubricity for napping and suedeing and the desired "hand" or "feel" required by the customer. Fluorocarbon finishing is an example of a functional finish for soil release or anti-staining properties. There is no bleaching, bonding, laminating, flocking or printing done at either of these plants.

BIOLOGICAL WASTEWATER TREATMENT FACILITIES

An extended aeration activated sludge treatment facility, with chlorination and post-aeration was in operation at the manufacturing facility at the initiation of the study. An engineering description of each component of the biological system is presented in Table 1. The normal operating parameters are presented in Table 2 and a schematic in Figure 1.

A brief description of the treatment sequence is as follows. Wastewater from two dyeing and finishing plants was screened and discharged into the aerated equalization tank. This tank was used for dampening chemical (organic) and hydraulic surges. Nitrate (as $NaNO_3$) was added to the equalization tank to provide nutrient to sustain biological activity. The waste was pumped from

TABLE 1. BIOLOGICAL TREATMENT PLANT ENGINEERING DATA

Flow	Units	3.0 MGD[1]	5.0 MGD[2]
EQUALIZATION TANK			
Detention	Hours	13.2	8.0
Volume	MG	1.65	1.65
	Cf	224,800.	224,800.
Aerators	No.	3	3
	Hp. (Each)	40.	50.
AERATION TANKS			
Detention	Hrs.	32.3	19.46
Volume, Total	MG	3.24	3.24
	Cf	433,690.	433,690.
Aerators Tanks #1 & 2*	No.	6	8
	Hp. Ea.	40.	40.
MLSS	mg/1	1,800.	3,000.
$\#BOD_5/\#MLSS$		.03	.03
* Tank #3: Existing Blowers			
SETTLING TANKS			
Detention	Hrs.	7.05	4.25
Overflow Rate	GPSFPD	318.	531.
Sludge Return	% Range	0-75	0-75
Return: To Aeration	MGD	2.25	3.75
To Mix	MGD	1.50	2.5
CHLORINATION FACILITIES			
Cl_2 Dosage	PPM	15.	15.
	PPD	375.	625.
Basin Volume	MG	.104	.104
	Cf	9,792.	9.792.
Contact Time	Min.	50	30
POST AERATION BASIN			
Detention	Hrs.	.70	.43
Volume	MG	.0875	.0875
	Cf.	11,700.	11,700.
Aerators	No.	2	2
	Hp. Ea.	5	5

(continued)

TABLE 1 (continued)

Flow	Units	3.0 MGD[1]	5.0 MGD[2]
SLUDGE DIGESTION			
Flow	MGD	.078	.130
Tank Volume	MG	.925	.925
	Cf.	123,300.	123,300.
MLSS	mg/l	22,500.	38,000.
Sludge Age	Days	24.3	24.3
Hydraulic Retention Time	Days	11.8	7.1
SLUDGE CONCENTRATOR			
Flow	MGD	.078	.130
Supernatant Flow Thru Detention	Hours	10.	6.
Overflow Rate	GPSFPD	81.	135.
Sludge Holding	Cf.	5,160.	5,160.
EXCHANGER & SOFTENER WASTE			
Flow estimated	MGD	.12	.188
Detention (both Tanks)	Days	4.1	2.66
Volume	MG	.50	.50
	Cf.	66,800.	66,800.
Aeration			Existing Blowers
SAND BEDS			
Number of Beds Existing		3	3
New		6	6
Total Area - Existing	Cf.	3,970.	3,970.
New	Cf.	25,000.	25,000.

Note 1: Data shown for 3.0 MGD flow commensurate with current operating conditions.

Note 2: Data shown for 5.0 MGD flow maximum Plant design.

TABLE 2. BIOLOGICAL SYSTEM - UNIT PROCESS DESCRIPTION

BIOLOGICAL TREATMENT PROCESS	
PROCESS	Activated Sludge
LOADING RATE	17.9 Lbs. BOD/1000 Cu.Ft./Day (Actual)
F/M RATIO	0.03 (Actual)
MLSS	6,500 - 8,500 mg/l (Actual)
AERATION BASINS	2 @ 1.62 MG Per Basin
DETENTION TIME	26 Hours @ 3 MGD (Actual)
AERATION	12 x 40 Hp Aerators = 480 Hp
MINIMUM D.O. LEVEL	3.0 mg/l
NUTRIENT FEED	100 Lbs./Day N_aNO_3 (33.5% Avail. N)
SECONDARY CLARIFICATION	
CLARIFIERS	2-75' Circular
SURFACE AREA	4418 Sq. Ft. Each, 8836 Sq. Ft. Total
SURFACE LOADING RATE	0.88 Lbs./Sq.Ft./Day (Actual)
SIDE WATER DEPTH (SWD)	13.5 Ft.
SURFACE OVERFLOW	318 Gal/Day/Sq.Ft. (Actual)
SURFACE OVERFLOW	531 Gal/Day/Sq.Ft. (Max. at 5.0 MGD)

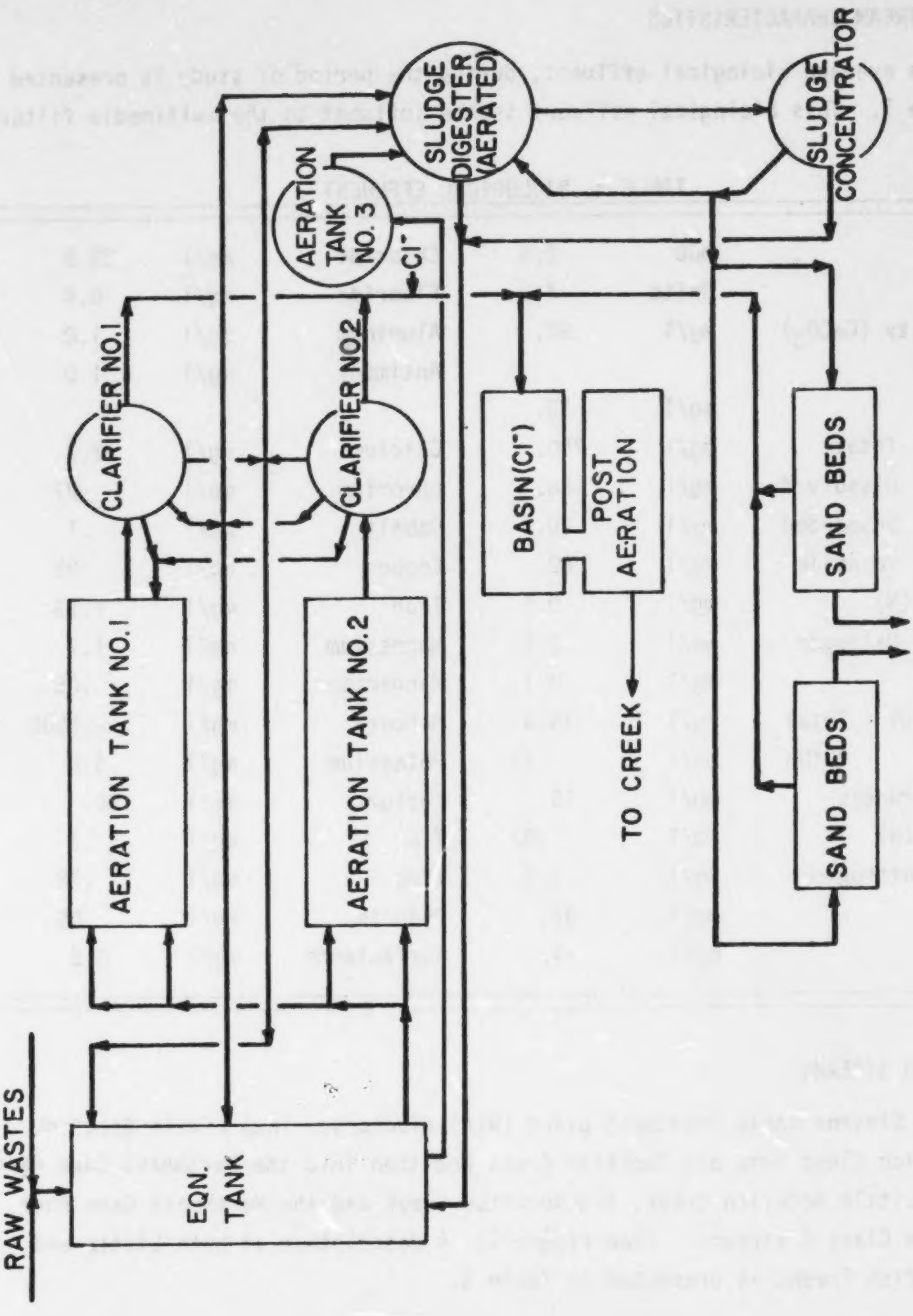

RAW WASTES
EQN. TANK
AERATION TANK NO.1
CLARIFIER NO.1
AERATION TANK NO.2
CLARIFIER NO.2
AERATION TANK NO. 3
Cl⁻
SLUDGE DIGESTER (AERATED)
BASIN (Cl⁻)
POST AERATION
TO CREEK
SLUDGE CONCENTRATOR
SAND BEDS
SAND BEDS
SOLIDS TO LANDFILL

Figure 1. Biological treatment system.

WASTE STREAM CHARACTERISTICS

The average biological effluent, during the period of study is presented in Table 3. This biological effluent is the influent to the multimedia filters.

TABLE 3. BIOLOGICAL EFFLUENT

Flow	MGD	2.9	Chloride	mg/l	28.0
pH	Units	7.2	Fluoride	mg/l	0.4
Alkalinity ($CaCO_3$)	mg/l	98.	Aluminum	mg/l	1.0
			Antimony	mg/l	1.0
BOD_5	mg/l	10.			
Solids - Total	mg/l	750.	Calcium	mg/l	2.7
Dissolved	mg/l	668.	Chromium	mg/l	.07
Suspended	mg/l	20.	Cobalt	mg/l	.1
Volatile	mg/l	82.	Copper	mg/l	.05
Ammonia (N)	mg/l	0.5	Iron	mg/l	1.73
Kjeldahl Nitrogen	mg/l	2.1	Magnesium	mg/l	1.7
Nitrate	mg/l	0.1	Manganese	mg/l	.05
Phosphorus - Total	mg/l	15.4	Mercury	mg/l	<.0005
Ortho	mg/l	.13	Potassium	mg/l	5.0
Total Hardness	mg/l	15.	Sodium	mg/l	99.
Nitrite (N)	mg/l	.03	Tin	mg/l	.3
Organic Nitrogen	mg/l	1.6	Zinc	mg/l	.28
Sulfate	mg/l	82.	Phenols	mg/l	.05
Sulfide	mg/l	<1.	Surfactants	mg/l	0.5

RECEIVING STREAMS

The Stevens waste treatment plant (WTP) discharges into Little Rockfish Creek which flows into Big Rockfish Creek and then into the Northeast Cape Fear River. Little Rockfish Creek, Big Rockfish Creek and the Northeast Cape Fear River are Class C streams. (See Figure 2) A description of both Little and Big Rockfish Creeks is presented in Table 4.

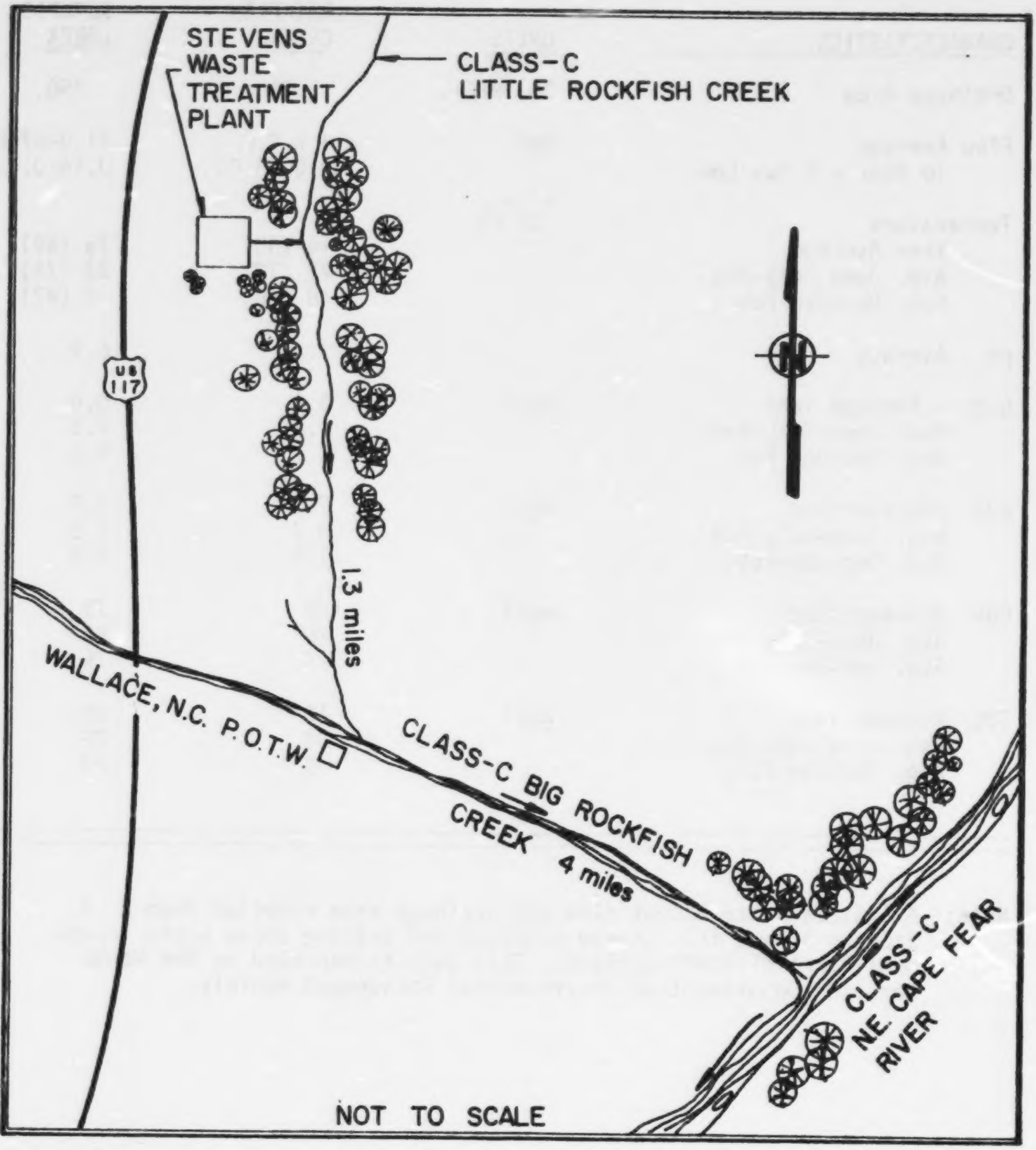

STEVENS
WASTE
TREATMENT
PLANT
CLASS-C
LITTLE ROCKFISH CREEK
N
US
117
1.3 miles
WALLACE, N.C. P.O.T.W.
CLASS-C BIG ROCKFISH
CREEK
4 miles
CLASS-C
NE. CAPE FEAR
RIVER
NOT TO SCALE

Figure 2. Receiving stream network in relation to wastewater treatment plant outfall.

TABLE 4. CHARACTERISTICS OF RECEIVING STREAMS UPSTREAM OF WASTEWATER TREATMENT PLANT DISCHARGE

CHARACTERISTICS	UNITS	LITTLE ROCKFISH CREEK	BIG ROCKFISH CREEK
Drainage Area	Sq. Miles	11.	150.
Flow Average	MGD	5.2-7.8	71.0-97.0
10 Year - 7 Day Low		0.00-0.03	0.16-0.63
Temperature	°C(°F)		
Year Average		14 (58)	15 (59)
Avg. June-July-Aug.		22 (72)	23 (74)
Avg. Dec-Jan-Feb.		8 (46)	8 (47)
pH Average - Year		7.2	6.9
D.O. - Average Year	mg/l	8.4	8.6
Avg. June-July-Aug.		7.4	7.5
Avg. Dec-Jan-Feb.		8.7	9.4
BOD Average Year	mg/l	2.3	2.9
Avg. June-July-Aug.		3.2	2.9
Avg. Dec-Jan-Feb.		1.8	2.8
COD Average Year	mg/l	28	79
Avg. June-July-Aug.		26	83
Avg. Dec-Jan-Feb.		25	75
TOC Average Year	mg/l	16	28
Avg. June-July-Aug.		34	29
Avg. Dec-Jan-Feb.		9	20

Note: All Stream Data except flow and drainage area compiled from J. P. Stevens & Co., Inc. stream sampling and testing above Waste Treatment Plant effluent outfall. This data is reported to the North Carolina Department of Environmental Management monthly.

the equalization tank to dual aeration units and to aeration tank #3. Aeration tank #3 was a part of an earlier contact activated sludge plant. The biologically treated wastewater was clarified and chlorinated. Effluent from the chlorine contact tank was aerated to 6-8 mg/l dissolved oxygen (D.O.) prior to discharge into Little Rockfish Creek. Aeration was necessary, as much of the year there was very little flow in the receiving stream. Residual chlorine in the effluent was below 0.5 mg/l.

Waste sludge and scum were pumped to an aerated sludge digester. Sludge from this digester flowed to a sludge concentrator and to sand beds for drying and final disposal to landfill.

Flow through the plant averaged approximately 2.9 MGD. All structures were designed for 5 MGD, but aeration equipment and floating aerators in the mix tank were provided for 4.0 MGD. When the 4.0 MGD flow was exceeded, or when additional aeration capacity was required, additional aerators were to be purchased and installed. Wiring and concrete pads on lagoon bottoms were already in place to accomodate additional and/or larger aerators as required.

SECTION 5

WASTEWATER TREATMENT PLANT OPERATIONAL CONSIDERATIONS

EFFECT OF CLARIFICATION ON MULTIMEDIA FILTRATION

The biological wastewater treatment system included two main secondary clarifiers, each seventy-five feet in diameter and having a 13.5 foot side wall water depth. Operating these clarifiers at a 3 MGD flow rate, with a mixed liquor suspended solids level of 7,000 - 7,500 mg/l, severely taxed the clarifiers. A change in flow to 3.5 MGD would require reduction of MLSS to 5,500 - 6,000 mg/l in order to maintain the same degree of secondary effluent quality. It was estimated that flow much above 3.5 MGD would require addition of a third secondary clarifier.

Efficient secondary clarification was absolutely essential to satisfactory performance of the multimedia filter tertiary wastewater treatment process. Poor secondary clarifier performance taxed the complete system. The multimedia filters were blinded very rapidly when secondary clarification was poor. This blinding caused excessive backwash requirements for the filters. A "chain reaction" was unleashed; the increased number and frequency of backwashes emptying into the equalization lagoon caused increased wastewater flow into aeration and subsequently to the secondary clarifiers. The poor clarification already in progress was made worse and the wastewater treatment plant efficiency was drastically reduced within a matter of two hours to the point that final effluent limits were exceeded and stream standards were violated. This condition had to be corrected at once to prevent an untenable situation - curtailment of the dyeing and finishing operations in both manufacturing plants.

The biological plant was designed with a large equalization lagoon and two large aeration lagoons. These three lagoons were normally operated at less than capacity. These lagoons provide approximately 1,250,000 gallons of temporary wastewater storage which could be used to quickly bring the system under control. This procedure was effectively demonstrated on several occasions. To control this chain reaction, the first step was to quickly reduce, by seventy-five percent, the wastewater entering the secondary clarifiers. This reduction was accomplished by partially closing the two hand-controlled gate valves which controlled wastewater flow by gravity to each clarifier. Under seventy-five percent reduced flow, the clarifiers efficiency was drastically improved within approximately fifteen minutes. After fifteen to thirty minutes, flow was increased gradually over a two to four hour period, until full flow was being satisfactorily clarified.

ADDITIONAL PROCESS DESIGN FEATURES

Three other design features in this biological system were vital to successful operation, and gave quick recovery from low clarifier solids removal efficiency. The first was a standby sludge recirculation pump piped to both clarifiers which could be used for either clarifier in the event of a sludge recirculation pump failure and which could also be operated to supplement sludge removal by the other two during a period of poor secondary clarifier performance. The sludge is pumped from secondary clarification to the headend of each aeration lagoon. The second was a clarifier drain pump; the importance of this small pump, common to both secondary clarifiers, cannot be overstated; it was used to draw off excessive concentrated sludge from the bottom of either or both clarifiers when clarification was less efficient. The primary purpose of this drain pump was to drain, or partially drain, either clarifier when problems occurred in that equipment. The third was a high turbidity alarm on the influent to the multimedia filters used to warn of high solids losses from the secondary clarifiers which would over-tax the filters, and eventually the entire system, if not brought under control quickly.

SUMMARY

The key to efficient and satisfactory operation of the multimedia filters was satisfactory, efficient, suspended solids removal by the secondary clarifiers. This point cannot be overstressed. The multimedia filters gave best pollutant and color removal performance, with or without chemical additions into the waste stream ahead of the filters, when their influent was secondary clarified wastewater containing low suspended solids.

SECTION 6

MULTIMEDIA FILTRATION

INTRODUCTION

The overall project consisted of three major efforts. The first being the operation and evaluation of the full-scale multimedia filtration; second, the operation of advanced waste treatment operations on bench and pilot scale to achieve water of manufacturing reuse quality as discussed in Section 7; and third, the reuse trials in laboratory scale, to determine if the treated effluent could be reused as discussed in Section 8.

OBJECTIVE

The objective of the operation of the multimedia filtration system, with or without chemical addition, following secondary biological treatment and chlorination, was to produce an effluent whose quality would meet stream standards and all effluent conditions imposed by the State of North Carolina and the National Pollutant Discharge Elimination System permit administered by the U. S. Environmental Protection Agency. This approach carried a high degree of risk. Table 5 provides multimedia filter engineering design criteria for this full-scale installation, designed for a maximum 5 MGD wastewater flow.

LOCATION

The location of the multimedia filtration system is shown schematically in Figure 3. A relatively small portion of the land area devoted to wastewater treatment was needed for this tertiary treatment, however, a substantial improvement in wastewater effluent quality was effected.

TABLE 5. MULTIMEDIA FILTRATION DESIGN CRITERIA
5 MGD MAXIMUM FLOW

Influent Pumps:		
Number	Each	3
Horsepower	Hp	40
Flow, Each	gpm	1,800
Total Dynamic Head	Ft.	60
Backwash Pumps:		
Number	Each	2
Horsepower	Hp	125
Flow, Each	gpm	7,000
Total Dynamic Head	Ft.	49
Surface Wash Pumps:		
Number	Each	2
Horsepower	Hp	15
Flow	gpm	200
Total Dynamic Head	Ft.	153
Water Supply Pumps:		
Number	Each	3
Horsepower	Hp	5
Flow	gpm	80
Total Dynamic Head	Ft.	129
Flow Measurement: Filter Influent		
Type	Magnetic Flow Meter	
Range	MGD	0-8
Size	Inches	12
Function	Indicate, Record, Totalize	
Mixed Media Filters:		
Number	Each	4
No. in operation at one time -	Each	3
Application Rate @ 5.0 MGD	GPSFPD	3.5
Length	Ft.	30
Diameter	Ft.	10
Surface Wash-Each Filter		Provided

(continued)

TABLE 5. (Continued)

Chemical Feed to Filters Provided:		
Alum:		
Liquid Alum Storage Tank Volume	Gal.	4000
No. Positive Displacement Pumps	Each	2
Polyelectrolyte:		
Tanks Provided: 250 Gallons	Mix	1
	Feed	1
Pumps	Each	2
Carbon:		
Storage Tank Volume	Gal.	18,000
Day Use Tank Volume	Gal.	1,500
Feed Pumps	No.	3
Transfer Pump	No.	1
Recirculation Pump	No.	1
Clear Backwash Water Storage (Existing)		
Volume	Gal.	69,000
Number of Filter Backwashes		1
Post Aeration Tank:		
Volume	Gal.	145,000
Surface Aerators - on hand	No.	2
Horsepower	Each	5
Flow Measuring: Plant Effluent		
Measuring Device		Parshall Flume
Size	Ft.	3.0
Function		Indicate, Record, Totalize

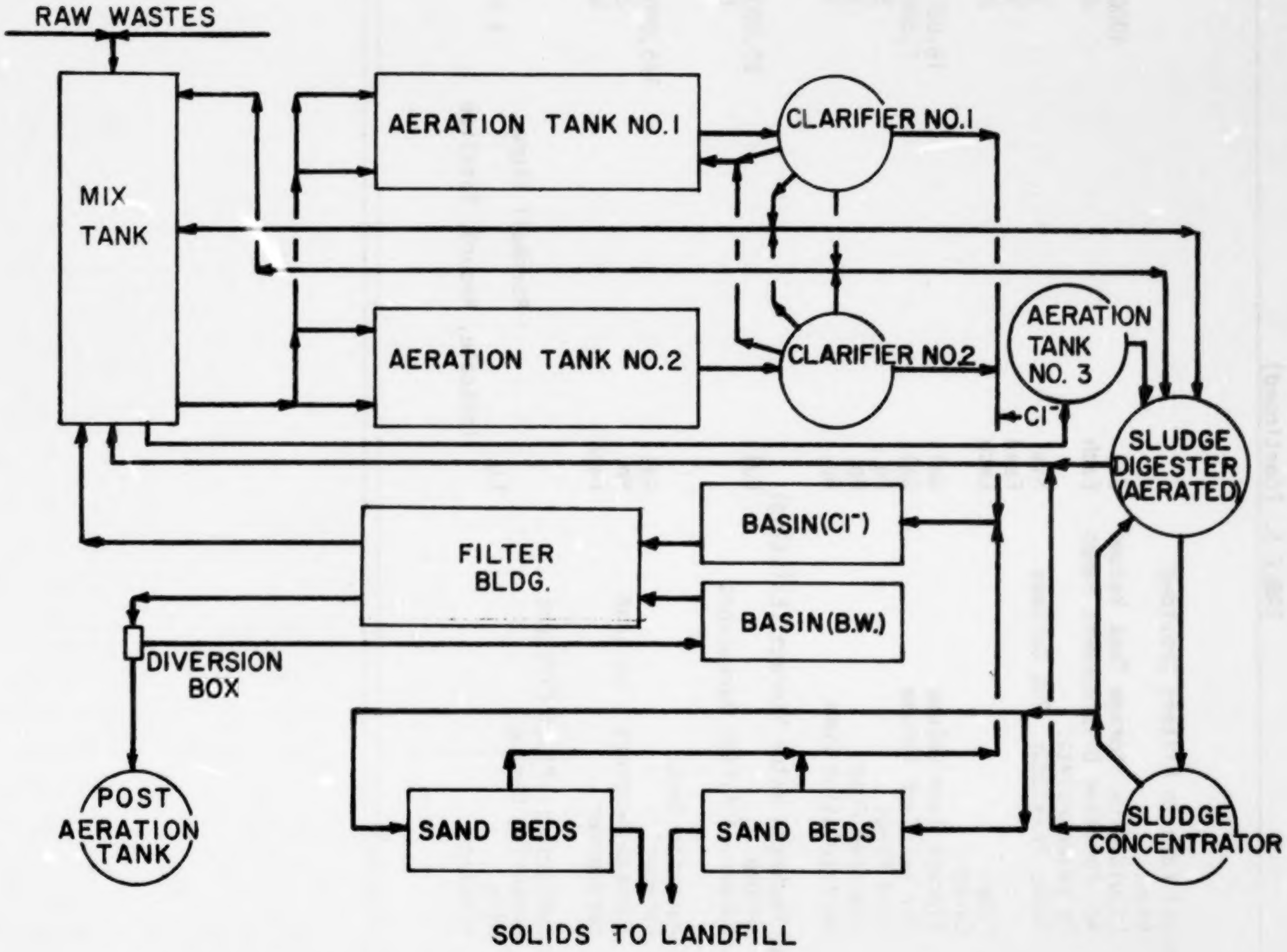

RAW WASTES
MIX TANK
AERATION TANK NO.1
AERATION TANK NO.2
CLARIFIER NO.1
CLARIFIER NO2
AERATION TANK NO. 3
Cl⁻
SLUDGE DIGESTER (AERATED)
BASIN(Cl⁻)
BASIN(B.W.)
FILTER BLDG.
DIVERSION BOX
POST AERATION TANK
SAND BEDS
SAND BEDS
SLUDGE CONCENTRATOR
SOLIDS TO LANDFILL

Figure 3. Biological treatment system with multi-media filter.

DESIGN/OPERATION

The system was designed with influent pumps, backwash pumps, and surface wash pumps for a 5 MGD flow. Filter effluent exited under pressure and was gravity fed to the final aeration tank where the dissolved oxygen was increased to 6.5 - 8.5 mg/l before discharge to the receiving stream.

Each multimedia filter was thirty feet long, and ten feet in diameter. The four filters were installed horizontally and operated in parallel. Approximately twenty-seven feet of each filter extended outside the building and was exposed to the ambient environment. This arrangement posed no problems with freezing since relatively mild winters are the norm in this Southeastern North Carolina location. Ambient temperatures are seldom below -4°C (25°F). The piping and valve network, turbidimeters, flowmeters, control panel, chemical feed pumps and lines, alum storage, polymer make-up and feed tanks, and carbon slurry day storage tank are all housed inside a building with heat available in extremely cold weather.

Flow to each filter was measured and controlled by metering the required amount of secondary effluent to each of the three filters kept on-line to treat the approximately 3.0 MGD flow. Normally, a fourth filter would be backwashed and placed on stand-by. However, if the characteristics of the secondary effluent were such that shorter filter runs were prevalent then all four filters could essentially be run at the same time. This was possible due to the fact that the backwash cycle took only 20 minutes from initiation to completion. Typically, the filters were set to backwash on a timed cycle of 24 hours, but each filter was also set to backwach on a high headloss override control. The headloss override was set to backwash each filter at eleven feet of headloss. The backwash flow rate was set at 5,500 gpm; the total backwash flow was approximately 40,000 gallons. Seventeen analog computer controlled valves had to be opened and/or closed from initiation to completion of the backwash cycle and bringing the filter back on line.

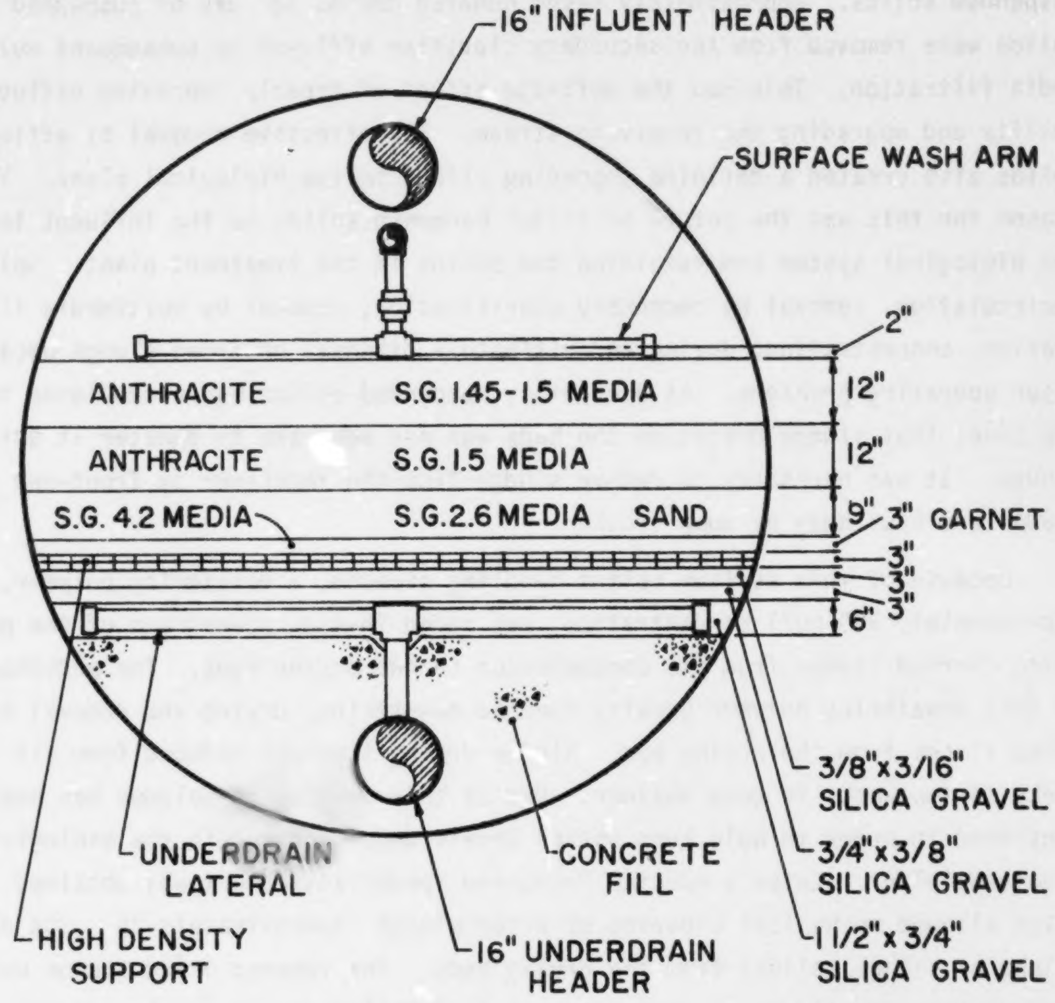
Analysis of solids in samples taken at the intervals shown, on the total backwash effluent line, for a selected filter backwash are shown in Table 6.

TABLE 6. ANALYSIS OF SOLIDS

Minute	Total Solids mg/l	Total Volatile Solids mg/l	Total Suspended Solids mg/l	Total Volatile Suspended Solids mg/l
1	1,720	1,265	1,536	1,208
5	875	520	560	444
8	655	330	372	272

Backwash water from the filters was returned by gravity to the equalization tank and again treated through the complete biological, chlorination, and tertiary filtration sequence. Backwash water was stored in a 87,500 gallon tank adjacent to the filter building. When the pre-set stored backwash storage water level was lowered, this tank was refilled by gravity flow, from multimedia filter effluent, from a splitter box located underground between the multimedia filter building and the post-aeration tank.

An end view of a multimedia filter is shown in Figure 4. Each filter was partially filled by twenty-eight tons of concrete which served as an anchor for tank stability and a base for support gravel and the underdrain system. A total of fifteen inches of varying size gravel was added on top of the concrete and made up the support bed and underdrain system. A total of thirty-six inches of four separate media added in length was placed above the gravel, hence the term multimedia filter. Filter influent was applied from the top through distribution laterals. The four media were stratified from coarse to fine from the top to the bottom. The mode of operation was to remove by physical filtration increasingly smaller particles as the wastewater, under pressure, was forced down through the increasingly finer media. Addition of coagulating chemicals was planned to improve efficiency by changing the physical form of pollutants into a form better removed by physical filtration. The addition of powdered activated carbon slurry improved pollutant removal by adsorption of pollutants on the carbon particles and also improved subsequent physical filtration.


16" INFLUENT HEADER
SURFACE WASH ARM
2"
12"
12"
9"
3" GARNET
3"
3"
3"
6"
ANTHRACITE
S.G. 1.45-1.5 MEDIA
ANTHRACITE
S.G. 1.5 MEDIA
S.G. 4.2 MEDIA
S.G. 2.6 MEDIA
SAND
3/8"x3/16" SILICA GRAVEL
3/4"x3/8" SILICA GRAVEL
1 1/2"x3/4" SILICA GRAVEL
UNDERDRAIN LATERAL
CONCRETE FILL
HIGH DENSITY SUPPORT
16" UNDERDRAIN HEADER

MEDIA LEVEL	S.G.	MEDIA TYPE	U.C.	MESH SIZE
1	1.45 - 1.5	ANTHRACITE	< 2.1	-4 to +14
2	1.5	ANTHRACITE	< 1.7	-8 to +20
3	2.6	SAND	< 1.8	+10 to +40
4	4.2	GARNET	< 2.0	+30 to +70

Figure 4. Multi-media filter, end view.

MULTIMEDIA FILTER SOLIDS HANDLING

One of the most important operational considerations was the removal of suspended solids. Approximately seven hundred pounds per day of suspended solids were removed from the secondary clarifier effluent by subsequent multimedia filtration. This had the definite effect of greatly improving effluent quality and upgrading the receiving stream. The effective removal of effluent solids also created a definite degrading effect on the biological plant. The reason for this was the return of filter backwash solids to the influent to the biological system and retaining the solids in the treatment plant. Solids recirculation, removal by secondary clarification, removal by multimedia filtration, concentration, drying and ultimately disposal of dried sludge became major operating problems. At one point, suspended solids had accumulated to the level that sludge drying on the beds was not adequate to dewater it quickly enough. It was necessary to remove sludge from the thickener by front-end loader and haul away by dump truck.

Because of this serious solids handling problem, a dewatering polymer, at approximately 200 mg/l concentration, was added in-line downstream of the pump which carried sludge from the concentrator to the drying beds. The addition of this dewatering polymer greatly speeded dewatering, drying and removal of dried sludge from the drying bed. Sludge drying time was reduced from six weeks to two weeks in good weather. Use of this dewatering polymer has been continued in order to help keep solids levels under control in the biological treatment plant. Later a special front-end loader attachment was obtained which allowed mechanical cleaning of dried sludge (approximately 25 - 30% dry weight of sludge solids) from the drying beds. The removed dried sludge was emptied into a solid waste container and land filled for disposal. It should be noted that even in rainy weather, good sludge dewatering can usually be accomplished within approximately two weeks in summer and three to four weeks in winter because cracking of the beds begins within twenty-four hours which allows rain water to drain away quickly. The only serious problem experienced was when very heavy rainfall pulverized wet or drying sludge and prevented cracking and quick drying; under those most adverse circumstances, some beds were not emptied sooner than six weeks, even when the dewatering polymer was used.

MULTIMEDIA FILTER POLLUTANT REMOVAL

The multimedia filters were employed both with and without prior chemical conditioning of the biologically treated effluent.

Without Chemical Addition

Table 7 shows monthly averages of pounds per day of BOD_5, COD and TSS, and Pt-Co Units of color removed by multimedia filtration without chemical addition. Removal was by physical filtration of suspended particles from the secondary clarified, chlorinated wastewater stream. It is apparent from this data that the multimedia filters were very effective in removal of pollutants by simple physical filtration. The average ratio of pounds of suspended solids to BOD_5 removed from January, 1974 through April, 1975 was 7.4:1, and the ratio of suspended solids to COD was 5.3:1. Expressed in another way, removal of one pound of suspended matter gave a resulting average daily removal of 0.19 pounds of COD and an additional 0.14 pounds of BOD_5. Color removal by this physical filtration was only an average of 41 Pt-Co Units of color or about 15% of the total color remaining after secondary clarification and chlorination. This low removal of color indicated a large amount of water soluble color.

Average pounds of pollutants remaining in the final effluent after physical treatment via multimedia filtration, without chemical addition, has been compared in Table 8 to the 3-stage NPDES Permit requirements for each parameter. The average residual color (Pt-Co) has been included for the same sixteen month period. All first stage (1/74-6/75) parameter averages were achieved except for one-month's averages for ammonia and oil and grease; the oil and grease value was suspected to be much lower and was attributed to analytical problems. Second stage (7/75-6/78) parameter averages would have been achieved for all but BOD_5 (five months) and suspended solids (four months). The monthly range in average pounds per day of BOD_5 and suspended solids removed via physical filtration was significant. Daily removals of BOD_5 ranged from 29 to 145 pounds and averaged 91 pounds per day based on monthly averages. The monthly average pounds per day of suspended solids removed ranged from 236 pounds to 948 pounds and averaged 671 pounds. These average daily pounds removed illustrate the achievement of NPDES Permit parameter requirements.

TABLE 7. POUNDS PER DAY POLLUTANTS PLUS AMOUNTS OF COLOR REMOVED VIA MULTIMEDIA FILTRATION (TERTIARY TREATMENT) WITHOUT CHEMICAL ADDITION

YEAR/MONTH	BOD_5	COD	SS	Pt-Co UNITS COLOR REMOVED*		
	Lbs/Day	Lbs/Day	Lbs/Day	Units Before	Units After	Total Units
1974						
January	118	706	236	195	177	18
February	81	670	393	253	198	55
March	83	740	344	241	201	40
April	99	1064	570	257	230	27
May	71	368	948	380	346	34
June	135	1962	539	376	300	76
July	145	2620	781	262	232	30
August	43	1358	644	238	222	16
September	54	1634	864	300	250	50
October	29	904	663	240	210	30
November	92	974	907	280	245	35
December	63	1502	593	170	147	23
1975						
January	124	1595	838	250	223	27
February	67	689	646	175	163	12
March	136	1913	925	340	240	100
April	112	1614	849	301	223	78

*Apparent color; run on unfiltered sample.

TABLE 8. AVERAGE POUNDS POLLUTANTS AND PT-CO UNITS OF COLOR REMAINING IN FINAL EFFLUENT AFTER MULTIMEDIA FILTRATION (WITHOUT CHEMICAL ADDITION) COMPARED TO 3-STAGE NPDES PERMIT REQUIREMENTS

Yr./ Mo.	BOD_5	SS	TKN	T PHOS.	T Cr.	T Zn.	NH_3	Sb.	Cu.	O&G	Phenols	Color
1974												
Jan.	205	377	172	151	1.5	3.7	8	28	1.8	447	1.8	
Feb.	146	254	98	120	1.1	4.4	7	39	1.9	123	2.9	
Mar.	168	173	90	135	1.2	5.5	7	24	1.6	112	1.6	
Apr.	203	376	123	162	1.1	9.6	15	39	2.1	103	1.7	225
May	251	271	129	211	1.1	9.2	14	24	2.7	435	1.6	346
June	305	359	135	182	1.0	4.9	14	20	2.0	341	1.0	300
July	272	370	171	100	1.4	6.8	29	24	2.8	930	4.6	232
Aug.	161	262	108	184	0.9	7.7	14	38	3.9	252	2.0	222
Sept.	140	303	117	133	1.1	7.7	16	28	3.0	268	2.3	246
Oct.	166	438	130	166	1.2	8.8	9.8	31	2.5	24	2.7	210
Nov.	241	502	133	190	1.3	5.5	7.7	13	2.6	46	9.2	245
Dec.	162	423	92	155	1.1	4.7	7.3	24	2.8	87	5.2	153
1975												
Jan.	164	353	97	174	1.1	5.6	11.2	11	2.0	195	3.4	223
Feb.	162	323	99	213	0.6	5.9	6.5	11	1.6	237	3.1	163
Mar.	213	436	121	72	0.6	5.3	6.4	16	0.9	170	1.2	240
Apr.	170	393	120	92	0.7	8.1	9.7	10	0.8	41	1.9	223
Average	196	351	121	153	1.1	6.5	11.4	24	2.2	238	2.9	233

NPDES PERMIT EFFLUENT REQUIREMENTS: STAGE 1 was for the period 1/74 - 6/75; STAGE 2 period was 7/75 - 6/78; STAGE 3 period 7/78 - 12/78 (*TKN may be higher provided permittee can show no resulting deleterious effects to stream biota or to stream quality).

STAGE												
1	375	1013	285	225	4.7	21	19	79	5.0	713	9.6	-
2	210	417	285	225	4.7	21	46	79	6.7	-	9.6	-
3	210	417	83*	225	2.0	12.5	46	21	0.8	-	4.0	-

The range in average pounds per day removed is more significant in light of biological treatment plant performance. A number of reasons have been cited why biological treatment plant performance varies. The presence of this tertiary treatment step downstream of the secondary clarifiers provided an additional safeguard in meeting NPDES Permit requirements and protecting the receiving stream. For comparison purposes, the concentrations of BOD_5, COD, SS (in milligrams per liter) and color (in Pt-Co Units) are given both before and after multimedia filtration, along with the average, standard deviation and coefficient of variation (CV) in Table 9. The CV is particularly useful in measuring the relative variation in more than one set of data. From the data in Table 9, it can be readily seen that the CV decreased for each of the parameters, indicating a more stable, consistently good quality effluent.

With Chemical Addition

There were three major factors which prompted additional investigations into optimization of the multimedia filtration process by chemical addition. The need for additional removal of suspended solids is evident from the data in Table 8, in order to comply with second and third stage NPDES Permit requirements. It was also important to determine the level of total Kjeldahl nitrogen (TKN) attainable. The effluent limits prescribed were thought to be practically unachieveable even with chemical addition. In order to reuse the water in dyeing, it was thought that greater than 90% of the color had to be removed. It was necessary to determine the practical limits of color removal by multimedia filtration with chemical addition in order to minimize the amount of additional color removal necessary in subsequent pilot scale treatment.

During the period when the multimedia filter installation was operated without chemical additives, laboratory bench work investigations with chemicals were performed. Alum was evaluated as the primary coagulant. Various polymeric coagulant aids were evaluated to find one or more which would greatly enhance the flocculating effects of alum in this particular waste stream. Powdered activated carbon slurry was evaluated alone and in combination with alum and alum/polymer at various concentration levels to determine what levels of removal of various pollutants and color could be achieved.

TABLE 9. EFFICIENCY OF MULTIMEDIA FILTRATION - WITHOUT CHEMICAL ADDITION

PARAMETERS	CONCENTRATION AFTER SECONDARY BIOLOGICAL TREATMENT				CONCENTRATION AFTER MULTIMEDIA FILTRATION					PERCENT REMOVAL BY MULTIMEDIA FILTRATION			
	BOD_5	COD	SS	COLOR Pt-Co	BOD_5	COD	SS	TOC	COLOR Pt-Co	BOD_5	COD	SS	COLOR Pt-Co
YEAR/MO	mg/1	mg/1	mg/1	units	mg/1	mg/1	mg/1	mg/1	units	%	%	%	%
1974													
January	13.7	320	26	195	8.7	290	16.0	87	177	36.5	9.4	38.5	9.2
February	9.8	265	28	253	6.3	236	11.0	71	198	35.7	10.9	60.7	21.7
March	11.2	264	23	241	7.5	231	7.7	70	201	33.0	12.5	66.5	16.6
April	12.8	326	40	257	8.6	281	15.9	72	230	32.8	13.8	60.3	10.5
May	14.0	304	53	380	10.9	288	11.8	76	346	22.0	5.3	77.7	8.9
June	18.6	367	38	376	12.9	284	15.2	77	300	36.0	22.6	60.0	20.2
July	17.0	403	47	262	11.1	296	15.1	89	232	34.7	26.6	67.9	11.4
August	8.1	285	36	238	6.4	231	10.4	73	222	20.5	18.9	70.8	6.7
September	8.3	314	50	300	6.0	244	13.0	82	250	27.7	22.3	74.0	16.7
October	8.0	288	45	240	6.8	251	17.9	99	210	15.0	25.3	60.2	12.5
November	13.0	304	55	280	9.4	266	19.6	98	245	27.7	12.5	64.4	12.5
December	9.3	282	42	170	6.7	220	17.5	85	147	28.0	22.0	58.3	13.5
1975													
January	12.8	310	53	250	7.3	239	15.7	77	223	43.0	22.9	70.3	10.8
February	10.6	261	45	175	7.5	229	15.0	78	163	29.2	12.3	66.7	6.9
March	16.4	358	64	340	10.0	268	20.5	89	240	39.0	25.1	68.0	29.4
Average	12.33	311.12	44.06		8.39	256.44	15.08						
Sta. Dev.	3.24	39.45	11.91		2.00	25.31	3.55						
C.V.	.26	.13	.27		.24	.10	.24						

Effect of Alum on Raw Influent Wastewater

Laboratory bench-scale studies were carried out on raw influent wastewater from dyeing and finishing to determine whether alum and alum/polyelectrolyte dosages could effect any significant removals of color, turbidity, COD, or TOC. This investigation was made to determine particularly whether significant color reductions could be realized; if so, then consideration would have been given to massive color reductions ahead of biological treatment.

Alum dosages of up to 200 mg/l alone (as alum), and with 1.5 mg/l of a cationic polyelectrolyte were used (See Table 10). All samples were filtered through glass fiber filters after mixing and settling in order to determine the greatest possible reductions by subsequent filtration in the four parameters investigated. This series of experiments yielded largely negative results. Color was not reduced in any of the eleven individual tests. Turbidity was not reduced when alum alone was used, and only a ten percent reduction when 1.5 mg/l of a cationic polyelectrolyte was added. Addition of alum alone gave COD reductions averaging approximately five percent, and only about ten percent when 1.5 mg/l of the cationic polyelectrolyte was added along with the alum. TOC results were interesting; there was no appreciable removal with alum or alum/polyelectrolyte if alum dosages were 125 mg/l or less. However, when alum dosages were increased to the 150 mg/l and 200 mg/l level there were eight and twenty-three percent reductions, respectively, in TOC values.

Following this laboratory exercise, experiments were designated to determine whether massive doses of alum (200 to 1,000 mg/l) would make any difference in color, turbidity, COD and TOC values. These parameters were tested on both filtered and unfiltered samples which had previously been treated with various alum dosages. Results were recorded in Table 11. Color reduction was not achieved in the unfiltered samples at any alum dosages; however, at 400 mg/l alum and higher, when samples were filtered, color was reduced from 800 to 500 Pt-Co Units. This reduction in color was not enough to prompt consideration of color removal ahead of biological treatment. Indications are that some organic dyes had been coagulated, but in a very fine floc which was not readily visible and which did not settle but was removed by filtration. Turbidity was generally increased as alum dosage increased, whether samples

TABLE 10. RAW WASTE RESPONSE TO ALUM & TO ALUM/POLYELECTROLYTE DOSAGES

SAMPLE #	pH (units)	ALUM (mg/1)	POLYELECTROLYTE mg/1	COLOR Pt-Co Units*	TURBIDITY JTU	COD (mg/1)	TOC (mg/1)
1	6.8	0	0	700	73	1152	328
2	6.2	75	0	700	74	1128	336
3	6.3	75	1.5	700	67	1072	320
4	6.1	100	0	700	72	1112	325
5	6.0	100	1.5	700	65	1040	295
6	5.9	125	0	700	87	1112	328
7	6.4	125	1.5	700	66	1120	317
8	6.1	150	0	700	73	1192	302
9	6.2	150	1.5	700	68	1120	284
10	6.2	200	0	700	78	1080	254
11	5.7	200	1.5	700	74	1040	289
12	6.2	0	1.5	700	73	1136	295

* True colors; run on filtered sample.

Mix: Rapid Mix 2 minutes @ 125 RPM; Add polyelectrolyte; Slow mix 25 Min. @ 25 RPM. Settle 15 minutes.

Filtration: Reeve Angle Glass Fiber Filters; 7.0 cm.

Temperature: 12°C. Due to refrigeration prior to experimentation.

Polyelectrolyte: Nalco 627, Cationic polyelectrolyte

TABLE 11. RAW WASTE RESPONSE TO ALUM

SAMPLE Number	ALUM mg/l	pH Units	Pt-Co COLOR Units*	TURBIDITY JTU	COD mg/l	TOC mg/l
1	0	7.0	800	82	1120	374
2	200	6.0	800	97	1104	342
3	400	5.1	800	125	1040	250
4	600	5.1	800	125	1048	302
5	800	5.1	800	125	1056	316
6	1000	4.8	800	125	1016	312
7	0	7.0	800	62	1088	344
8	200	6.0	800	75	1072	320
9	400	5.1	500	70	640	236
10	600	5.1	500	72	632	225
11	800	5.1	500	86	736	246
12	1000	4.8	500	93	776	Broke

* Filtered samples yield true color; unfiltered yield apparent color.

Mix: Rapid mix 2 minutes @ 125 RPM; Add Alum; Slow mix @ 20 RPM - 25 Min. Settle 15 minutes.

Floc: Virtually no floc noted in any sample.

Temperature: 12°C.

Filtration: Samples 1-6 decanted. Samples 7-12 filtered through 934AH Reeve Angle glass fiber filter, 7 cm.

were filtered or unfiltered. Based on these results, it was decided to use a filtered rather than decanted sample in evaluating chemical addition pollutant removal efficiency; as the filtered sample was thought to be more nearly representative of the full-scale multimedia filter performance and provide a more consistent evaluation of results.

COD reductions on the unfiltered samples amounted to approximately five to ten percent when alum dosages were increased beyond 200 mg/l. The COD reductions on the filtered samples were approximately forty percent at 400 and 600 mg/l, but only approximately thirty percent at 800 and 1,000 mg/l alum. These removals indicate some definite chemical coagulation had taken place. Like COD removal, 200 mg/l alum had little effect on TOC removal. However, at 400 mg/l alum, TOC removal was approximately sixteen percent on the unfiltered samples and approximately thirty percent on the filtered samples.

This series of experiments indicates explicitly that alum, even in extremely large dosages, would not exert a significant pollutant reduction. Significant pollutant reduction by alum treatment of raw influent wastewater was not expected however, because of the high amounts of soluble pollutants such as acid and basic dyes and other soluble organics. Had this approach worked to give reductions of color, TOC and COD of more than fifty percent, coagulation and settling ahead of biological treatment would have been considered.

Effect of Alum on Secondary-Clarified, Non-Chlorinated Wastewater

Laboratory jar tests were made on secondary-clarified, non-chlorinated, wastewater using only alum as a primary coagulant. The plan was to determine maximum coagulation efficiency using alum and then to determine in a later series of bench tests what additives might improve the coagulation efficiency of alum. Two series of tests were made; the first was alum added in 100 or 200 mg/l increments to 600 mg/l, and the second was alum added in 50 mg/l increments to 250 mg/l as shown in Table 12.

Maximum color and COD removal was obtained at 200 mg/l additions of alum to 600 mg/l gave no further removals. BOD_5 was only significantly affected at 400 mg/l. Greatest removal efficiency was obtained with 150 mg/l alum;

TABLE 12. LABORATORY EXPERIMENTS - EFFECTS OF ALUM ON POLLUTANT REDUCTIONS IN BIOLOGICALLY TREATED, SECONDARY-CLARIFIED, NON-CHLORINATED WASTEWATER

SAMPLE #	ALUM mg/l	Pt-Co COLOR Units*	% COLOR REMOVED	TURBIDITY JTU	COD mg/l	TOC mg/l	BOD_5 mg/l	OBSERVATIONS FLOC
A1	0	320	0	1.0	228		8	None
2	50	240	25	1.3	204		8	Cloudy
3	100	160	50	1.5	176		7.5	Pin
4	200	60	81	0.7	100		8	Large
5	400	80	75	0.7	100		1	Large
6	600	80	75	0.9	104		1.5	Large
B1	0	280	0	1.5	208	114	7.3	None
2	50	280	0	3.1	208	78	6.6	None
3	100	240	14	7.5	180	72	9.3	Pin
4	150	80	71	2.1	96	42	5.3	Large
5	200	60	79	1.2	84	38	2.0	Large
6	250	40	86	1.2	88	36	7.3	Large

* True color; run on filtered sample.

a. Flash mix 2 minutes @ 125 RPM. Add Alum mix 5 minutes. Mix at 20 RPM 5 minutes. Settle 20 minutes. Filter.

b. Filter through 7.0 cm 934AH Reeve Angle Glass Fiber Filter.

c. Initial Waste pH 7.2 Temperature 12°C.

d. BOD_5 determinations: 15% Sample. Not Seeded.

although slightly higher removals of BOD_5, COD and color could be obtained at 200 and 250 mg/l. The incremental removal efficiency at these higher dosages was not considered to be economically feasible.

There was one encouraging observation from these experiments. Pin floc (very small, poor settling floc) was noted at approximately 100 mg/l alum. This indicated that lower alum dosages added to the wastewater ahead of the multimedia filters would give a pin floc which would be captured by the denser filter media layers. Consideration was given to the fact that BOD_5 removals were poor in these two similar experiments. The most plausible reason for this was the fact that laboratory experiments had shown that 84% of the BOD_5 was soluble and, therefore, the type not likely removed by coagulation. Additionally, the BOD_5 test itself likely did not adequately differentiate BOD_5 from sample to sample at this very low concentration.

pH Versus Alum Coagulation Efficiency

Laboratory bench-scale experiments were conducted to evaluate the effect of pH on color and pollutant removals when 150 mg/l alum was used on the biologically-treated, secondary-clarified, non-chlorinated wastewater. As expected, color and other pollutants were generally coagulated and removed with greater efficiency as pH was lowered to 6.0, but data indicated going below 6.0 pH would be of questionable value. Unfiltered blanks were compared with the filtered blanks. Color was generally not affected simply by filtering. However, reductions in other pollutants were noticeable. See Table 13.

Chlorinated Vs. Non-Chlorinated Wastewater

Laboratory jar tests were conducted to determine whether significant differences in pollutant removals would be evident when comparing secondary-clarified, biologically-treated wastewater, chlorinated vs. non-chlorinated. This study was conducted for two reasons. It was necessary to know whether chlorinated, secondary-clarified wastewater could be treated with alum, powdered activated carbon, and various polyelectrolytes to yield a floc suitable for removal by multimedia filtration. If the chlorinated wastewater could not be so treated, then it would be necessary to relocate the chlorination facility downstream from the multimedia filters, just prior to final

TABLE 13. EVALUATION OF COLOR AND POLLUTANT REMOVALS WITH 150 mg/1 ALUM AT VARIOUS pH'S

SAMPLE #	ALUM mg/1	Pt-Co COLOR Units*	% COLOR REMOVAL	TURBIDITY JTU	COD mg/1	BOD_5 mg/1	pH Units	OBSERVATIONS FLOC
A1	0-Unf	300	0	15.0	304	20.8	7.3	None
2	0-	280	7	6.2	256	7.6	7.3	None
3	150	160	47	4.9	148	4.8	7.0	Large
4	150	120	60	4.0	124	5.2	6.5	Large
5	150	60	80	0.8	100	4.8	6.0	Large
6	150	80	73	0.9	96	5.2	5.2	Large
B1	0-Unf	320	0	3.8	332	9.2	7.3	None
2	0	320	0	2.1	308	5.2	7.3	None
3	150	160	50	4.5	208	5.2	7.0	Large
4	150	160	50	3.7	188	4.4	6.5	Large
5	150	80	75	1.4	168	3.6	6.0	Large
6	150	120	63	0.9	160	4.8	5.5	Large

* True color; run on filtered sample.

Note: Samples A-1 and B-1 are unfiltered blanks for comparison.

Procedure:
a. Add Alum and rapid mix @ 125 RPM 2 minutes.
b. Reduce mixing to 50 RPM - Adjust pH (HCL).
c. Reduce mixing to 20 RPM and mix 25 minutes.
d. Settle for 15 minutes.
e. Filter Supernatant through 934 AH Reeve Angle Glass Fiber Filter, 7.0 cm.

aeration and discharge. This study revealed no differences significant enough to warrant evaluating only non-chlorinated, secondary-clarified wastewater. See Tables 14 and 15 for comparative color, COD and TOC results.

Prior laboratory studies had shown that 150 mg/l alum was needed to significantly and consistently reduce color in this wastewater. Additional evaluations were conducted using alum and powdered activated carbon to combine several investigations into one: (1) chlorinated versus non-chlorinated secondary wastewater; (2) powdered activated carbon dosages of 10 to 300 mg/l; and (3) 100 mg/l alum dosages with powdered activated carbon. Results of these investigations are summarized in Tables 14 and 15. Several major findings resulted from these investigations. In this particular wastewater, color was well removed when 150 mg/l alum was used but very poorly removed when alum dosages were lowered to 100 mg/l, even when powdered activated carbon was used. It was evident that polymeric coagulant aids must be evaluated to greatly improve alum efficiency for color removal; these investigations were made in a later series. The pollutant removal efficiency of powdered activated carbon in the jar tests was quite poor; even massive dosages gave only limited color removals. COD and TOC removal efficiencies by powdered activated carbon additions were judged economically infeasible; removals via alum or alum/polymer coagulations required further investigations for optimization to improve the economics of removal.

The data in Tables 14 and 15 provide some very interesting insights into pollutant removals in this particular waste. The 150 mg/l alum dosage removed approximately 50% of the COD and TOC, and 60-70% of the color. However, even 100 mg/l powdered activated carbon gave only a 20-30% additional reduction in these parameters. This 100 mg/l dosage of powdered activated carbon, considering the incremental removal, was considered economically prohibitive.

Pollutant Removal By Powdered Activated Carbon Alone

Powdered activated carbon was evaluated alone to determine its effectiveness for pollutant removal. This would determine whether interference from alum had been a factor in the previous investigations. The results of these investigations are given in Table 16. Powdered activated carbon dosages of 100 mg/l were required to effect significant removals. Powdered activated carbon dosages of 200 mg/l had no additional significant effect on color, COD

TABLE 14. LABORATORY EXPERIMENTS - EFFECTS OF ALUM AND POWDERED ACTIVATED CARBON ON NON-CHLORINATED, SECONDARY CLARIFIED, BIOLOGICALLY TREATED WASTEWATER

SAMPLE #	ALUM mg/l	PAC mg/l	Pt-Co COLOR Units*	TURBIDITY JTU	COD mg/l	TOC mg/l	OBSERVATIONS
1	0	0	200	2.2	248	80.	No floc
2	150	0	80	2.1	124	41.8	Med floc; slight settling
3	150	10	80	2.2	116	40.6	Med floc; some settling
4	150	25	80	2.2	108	35.5	Med floc; some settling
5	150	35	80	2.4	116	40.3	Med-large floc; good settling
6	150	50	80	2.2	100	45.8	Med-large floc; good settling
7	0	0	240	3.3	224	80.9	No floc
8	150	0	80	2.8	112	38.8	Med floc; slight settling
9	150	100	60	2.4	80	35.5	Med floc; good settling
10	150	150	40	2.8	76	26.5	Med floc; good settling
11	150	200	40	2.4	60	25.6	Med floc; good settling
12	150	300	30	2.1	40	20.8	Med floc; good settling

* True color; run on filtered sample.

Notes

a. Flash mix alum 2 minutes @ 125 RPM; Carbon slurry added = Mix 5 minutes @ 125 RPM; Alum slurry added - Mix 5 minutes @ 2- RPM; Settle 20 minutes.

b. Filter samples through 934AH 7.0 cm Reeve Angle Glass Fiber Filter.

c. Initial pH of waste sample 7.3 for samples 1-6; and 7.5 for samples 7-12.

d. Temperature of all samples 15°C.

e. PAC with Westvaco Aqua Nuchar A.

TABLE 15. LABORATORY EXPERIMENTS - EFFECTS OF ALUM AND POWDERED ACTIVATED CARBON ON NON-CHLORINATED, SECONDARY CLARIFIED, BIOLOGICALLY TREATED WASTEWATER

SAMPLE #	ALUM mg/l	PAC mg/l	Pt-Co COLOR Units*	TURBIDITY JTU	COD mg/l	TOC mg/l	OBSERVATIONS
1	0	0	280	1.6	236	76.9	No floc
2	150	0	80	2.4	120	40.6	Pin floc; some settling
3	150	25	80	1.6	116	33.8	Med floc; good settling
4	150	35	100	2.5	100	36.5	Med/large floc; good settling
5	150	50	100	3.7	104	34.9	Med/large floc; good settling
6	150	100	60	1.8	80	30.8	Med/large floc; good settling
7	150	150	80	3.0	76	22.8	Med/large floc; good settling
8	150	200	40	3.0	68	22.9	Med/large floc; good settling
9	150	300	20	1.8	56	18.5	Med/large floc; good settling
10	100	25	200	8.3	188	94.2	Pin floc
11	100	50	200	8.9	176	65.2	Pin floc
12	100	100	200	9.7	148	55.6	Pin floc

* True color; run on filtered sample

a. Flash mix 2 minutes @ 125 RPM; Carbon slurry added = mix 5 minutes @ 125 RPM; Alum slurry added. Mix 5 minutes @ 20 RPM; Settle 20 minutes.

b. Filter samples through 934AH Reeve Angle Glass Fiber Filter.

c. Initial pH of wastewater sample was 7.2

d. Temperature of all samples was 15°C.

e. PAC - Westvaco Aqua Nuchar A.

TABLE 16. COLOR, TURBIDITY, COD, TOC, REMOVED BY POWDERED ACTIVATED CARBON ADDITION TO SECONDARY CLARIFIED, CHLORINATED WASTEWATER

SAMPLE #	PAC mg/1	Pt-Co COLOR Units*	TURBIDITY JTU	COD mg/1	TOC mg/1	OBSERVATIONS FLOC
1	0	200	2.2	204	79.8	None
2	25	200	2.5	204	76.0	None
3	50	200	3.8	196	77.5	None
4	100	120	5.3	144	61.0	Pin
5	150	80	2.0	100	47.5	Good
6	200	120	17.0(1)	148	49.5	Good
7	250	20	0.8	100	31.8	Small
8	300	20	0.7	84	29.0	Pin
9	350	-	-	-	-	-
10	400	30	0.7	96	27.0	Small
11	450	-	-	-	-	-
12	500	40	0.8	88	28.0	Small

* True color; run on filtered sample.

(1) Floc broken by handling.

Procedure: Rapid Stir 1 Minute. Add PAC, stir 2 minutes @ 125 RPM, Stir 28 Minutes @ 20 RPM. Settle 30 Minutes. Filter through 7.0 cm Diam. 934AH Reeve Angle Glass Fiber Filter.

Powdered Activated Carbon: Westvaco Aqua Nuchar A.

and TOC. Dosages of 300 mg/l did effect greater removals. Dosages of 400 and 500 mg/l provided significant improvement. Regression equations were fitted to the data in Table 16. These were of the form y=a+bx. Correlation coefficiants as a measure of "goodness of fit", were developed for color, COD and TOC (Samples 1-9); these were 0.94, 0.91 and .98 respectively. The correlation values indicate a very strong correlation and consistent results.

Experiments other than those presented in Table 16 gave similar results, even when a contact time of four hours was used. A telephone communication with the technical service group of a major powdered activated carbon supplier gave the response that 100 mg/l of powdered activated carbon would be about the maximum dosage which could be economically considered. With this particular wastewater, earlier laboratory results had shown that greater color and pollutant removals were obtained using alum at 150 mg/l than with large carbon dosages. Should no other chemical system prove practical, then the most important consideration for full-scale application ahead of the multimedia filter was the evaluation of powdered activated carbon cost versus the cost and inconvenience of coping with extremely large amounts of alum sludge.

Further tests were made with another PAC slurry. The results of this carbon (Sample B) were compared with the carbon used in the previous investigations (Sample A). From Table 17, it is apparent that Sample A carbon is superior to Sample B carbon in all respects. Therefore, it was decided to use only Sample A carbon or its equivalent in further laboratory and full-scale plant trials.

Alum/Polymer Dosages for Color and Pollutant Removals

A series of laboratory experiments was carried out to study further the effects of alum, alum/polymer and polymer alone on color and pollutant removals from secondary treated wastewater. Care was taken to use samples with varying color. Previous tests had shown that chlorination had no unsatisfactory effect on results; however, chlorinated wastewater was not used to assure that wastewater color was unaffected by chlorine oxidation. The type and amount of dye varied throughout the day, and from day to day, in the wastewater from the manufacturing plants. On any given day, the color in the secondary wastewater would be affected more or less by the amount of soluble dyes present.

TABLE 17. EVALUATION OF POWDERED ACTIVATED CARBON ALONE AS A COLOR AND POLLUTANT REMOVAL CHEMICAL

SAMPLE #	PAC mg/l	Pt-Co COLOR Units *	% COLOR REMOVED	TURBIDITY JTU	COD mg/l	BOD_5 mg/l	TOC mg/l
A1	0-Unf	500		9.0	400		105
2	0-F	500	0	7.8	356	28	92
3	25	300	40	3.5	284	23	81
4	50	300	40	3.7	268	23	79
5	100	200	60	4.5	256	22	82
6	200	200	60	4.6	232	22	64
7	400	200	60	5.5	192	21	
B1	0-Unf	500		120.	484		182
2	0-F	500	0	7.7	448		167
3	25	400	20	8.6	444		166
4	50	400	20	9.0	412		161
5	100	300	40	9.7	392		156
6	200	300	40		340		143
7	400	150	70		272		118

* Filtered samples yield true color; unfiltered yield apparent color.

Note:
1. Sample A's run using Westvaco's Powdered Activated Carbon NUCHAR AQUA A.
2. Sample B's run using Westvaco's Powdered Activated Carbon C-190-N.
3. Samples A-1 and B-1 are unfiltered blanks (no PAC).
4. Samples A-2 and B-2 are filtered blanks (no PAC).
5. Temperature of Wastewater 22°C (72°F).
6. Wastewater pH 7.2 on A series and 7.5 on B Series.

Running Procedure:

a. Add powdered activated Carbon - Rapid mix at 125 RPM - 2 minutes.
b. Reduce mixing speed to 20 RPM for 25 minutes.
c. Settle 15 minutes.
d. Filter supernatant through 7.0 cm. 934AH Reeve Angle Glass Fiber Filter.

Color and pollutant removals in this particular series of laboratory experiments was by chemical coagulation and settling, except for filtration of some samples for comparison evaluation. The data is presented in Table 18. Careful attention should be given the data in Tables 18, 19 and 20, in order to compare color and pollutant removals with varying amounts of alum and/or polymeric coagulant aid. The cationic coagulant aid used was chosen after preliminary evaluation of a number of such materials in the laboratory.

Color removal by alum alone was best at 125-150 mg/l, as had been previously determined for this particular waste. The tremendous increase in color removal by addition of cationic coagulant polymer was of particular interest; addition of 1.5 to 2.5 mg/l polymer effected much greater removals than alum alone; the use of 5 mg/l gave no further improvement. Indications were that 1.5 mg/l or less polymer could likely be used with good results in the more dynamic full-scale multimedia filter plant.

COD removal by alum was enhanced by polymer addition. It was interesting to note that a doubling of alum/polymer concentration gave essentially a doubling of COD removal. The percentages of BOD_5 removal were higher at the 75 mg/l alum and 1.5-2.5 mg/l polymer dosages than were percentages of COD removed. Furthermore, as the alum level was doubled, the COD removal was less than doubled. The fact that most samples in this series were simply settled and decanted for testing as opposed to settling and filtration through glass fiber filter medium likely added to the less obvious concentration shifts.

As with color removal, BOD_5 and COD removals were not increased by increasing coagulant aid polymer concentration. Of particular importance is the fact that addition of only the coagulant aid polymer without alum resulted in no visible floc formation and no removal of color, BOD_5 and COD. To the contrary, the use of polymer only gave an increase in BOD_5 and COD concentrations which was an indication the polymer itself exerted an oxygen demand.

The major concern was to determine what additional color and pollutant removals could be obtained in full-scale filtration and determine what problems would have to be overcome to meet requirements for all stages of the NPDES Permit (See Table 21) and to produce a more economically treated, low color wastewater which would be further treated in the pilot studies in an attempt to produce water suitable for reuse in dyeing and finishing.

TABLE 18. EVALUATION OF ALUM AND ALUM/POLYMER DOSAGES ON COLOR AND POLLUTANT REDUCTIONS IN BIOLOGICALLY-TREATED, SECONDARY-CLARIFIED, NON-CHLORINATED WASTEWATER

SAMPLE #	ALUM mg/l	CATIONIC POLYMER mg/l	Pt-Co COLOR Units*	% COLOR REMOVED	TURBIDITY JTU	COD mg/l	BOD$_5$ mg/l	pH Units
1	0	-	320	-	21.8	308	8.8	7.0
2	75	-	320	0	9.2	284	5.6	6.9
3	75	2.5	320	0	4.3	260	5.6	6.8
4	100	-	300	6	18.0	272	4.8	6.8
5	100	2.5	280	13	4.5	256	4.4	6.6
6	125	-	320	0	12.	256	5.2	7.0
7	125	2.5	200	38	4.6	220	4.0	6.8
8	150	-	240	25	17.0	216	3.6	6.5
9	150	2.5	160	50	4.9	196	4.0	6.7
10	150	5.0	200	38	5.9	216	4.8	6.7
11	0	2.5	320	0	5.0	328	12.0	7.1
12	0	5.0	380	19+	5.6	348	11.2	7.2

* Apparent color; run on unfiltered sample.

Note:
1. Samples NOT Filtered.
2. Alum alone produced a good floc which settled well.
3. Alum and polymer caused floc to form large clumps which settled rapidly.
4. Polymer alone produced no visible floc.
5. Wastewater Temperature 21°C (70°F).
6. Polymer used was Nalco 627.

Procedure:

a. Add chemical under rapid mix conditions (125 RPM).
b. Rapid mix 2 Minutes @ 125 RPM.
c. Slow mix 20 Minutes @ 25 RPM.
d. Settle 30 Minutes. Decant supernatant for testing.

TABLE 19. EVALUATION OF ALUM AND ALUM/POLYMER DOSAGES ON COLOR AND POLLUTANT REDUCTIONS IN BIOLOGICALLY-TREATED, SECONDARY-CLARIFIED, NON-CHLORINATED WASTEWATER

SAMPLE #	ALUM mg/l	CATIONIC POLYMER mg/l	Pt-Co COLOR Units*	% COLOR REMOVED	TURBIDITY JTU	COD mg/l	TOC mg/l	BOD_5 Units
1	0	0	420		1.2	256	96	7.3
2	75	0	350	17	2.5	232	89	7.1
3	75	2.5	350	17	1.6	216	71	7.3
4	100	0	300	29	3.3	212	77	7.0
5	100	2.5	250	40	1.9	200	63	7.3
6	125	0	200	52	3.9	200	77	6.9
7	125	2.5	280	33	5.1	172	72	6.6
8	150	0	350	17	19.0	172	69	6.7
9	150	2.5	280	33	6.0	156	64	6.5
10	150	5.0	280	33	6.8	156	70	6.6
11	0	2.5	420	0	4.9	268	106	7.1
12	0	5.0	420	0	5.5	268	106	7.1

* Apparent color; run on unfiltered sample.

Notes:
1. Samples NOT Filtered.
2. Alum alone produced a good, well settling floc.
3. Alum/Polymer floc formed large clumps which were very rapidly settled.
4. Polymer alone produced no visible floc.
5. Temperature of wastewater was 21°C (70°F).
6. Polymer used was Nalco 627.

Procedure:

a. Add chemicals under rapid mix conditions (125 RPM).
b. Rapid mix 2 Minutes @ 125 RPM.
c. Slow mix 25 Minues @ 20 RPM.
d. Settle 30 Minutes. Decant supernatant for testing.

TABLE 20. EVALUATION OF ALUM AND ALUM/POLYMER DOSAGES ON COLOR AND POLLUTANT REDUCTIONS IN BIOLOGICALLY TREATED, SECONDARY CLARIFIED, NON-CHLORINATED WASTEWATER

SAMPLE #	mg/l	CATIONIC POLYMER mg/l	Pt-Co COLOR Units*	% COLOR REMOVED	TURBIDITY JTU	COD mg/l	TOC mg/l	BOD$_5$ mg/l
1	0-Unf	0	500	0	25.0	450	-	-
2	0-F	0	500	0	22.0	400	123	28.0
3	75	0	300	40	18.0	328	104	27.5
4**	75	1.5	200	60	10.0	304	81	-
5	100	0	300	40	18.0	316	86	29.5
6**	100	1.5	200	60	9.0	260	65	-
7	125	0	300	40	16.0	260	79	22.0
8**	125	1.5	100	80	5.8	196	75	-
9	150	0	100	80	6.0	200	80	24.0
10**	150	1.5	125	63	5.8	168	70	-
11**	150	2.5	125	63	6.1	168	69	-
12**	0	1.5	300	40	9.2	368	122	-
13**	0	2.5	300	40	9.5	360	130	-

* Filtered samples yield true color; unfiltered yield apparent color.

Notes:
1. * Denotes samples which could NOT be filtered.
2. Alum produced a large, light floc.
3. Alum/polymer floc was very large and did not settle well.
4. Polymer alone produced no visible floc.
5. Temperature of wastewater used for 22°C (72°F).
6. Polymer used was Nalco 627.
7. Clarifier effluent used was very highly colored, cloudy, and contained high suspended solids (not measured).

Procedure:

a. Add chemicals under rapid mix conditions (125 RPM).
b. Rapid mix 2 Minutes @ 125 RPM.
c. Slow mix 25 Minutes @ 20 RPM.
d. Settle 15 Minutes. Decant supernatant.
e. Attempt to filter all decanted supernatants through 7.0 cm 934AH Reeve Angle Glass Fiber Filter.

TABLE 21. NPDES DISCHARGE REQUIREMENTS, 3 - STAGE PERMIT

STAGE	1	2	3
PERIOD:	1/74-6/75	7/75-6/78	7/78-12/78
	Average Pounds/Day	Average Pounds/Day	Average Pounds/Day
PARAMETERS:			
FLOW MGD*	5.0 MGD*	5.0 MGD*	5.0 MGD*
BOD$_5$	375	210	210
T.S.S.	1,013	417	417
T. Kjeldahl Nitrogen	285	285	83
T. Phosphorus	225	225	225
T. Chromium	4.7	4.7	2.0
T. Zinc	21	21	12.5
Ammonia	19	46	46
Antimony	79	79	21
Copper	5	6.7	0.8
Oil and Grease	713	-	-
Phenols	9.6	9.6	4.0

Stage 1: Average Pounds Per Day shown for Discharge 002 - Wastewater Treatment Plant Effluent only. The other three discharges not included.

Stages 2 & 3: All four discharges are combined into a single discharge.

Discharges are: Boiler Blowdown, Wastewater Treatment Plant, Acid/Brine Discharge and Cooling Water Overflow Discharge.

Pilot Media Filter Chemical Evaluation

Following extensive laboratory evaluations of a large number of coagulant aids and polymeric primary coagulants, a polymer manufacturer offered a 2-gpm pilot media filter for a dynamic evaluation of various polymeric coagulants, alum and combinations of alum and polymers. This unit was operated on site inside the filter building.

Secondary, chlorinated wastewater was taken from the influent to the multimedia filters and fed to the 2-gpm pilot filter. Several interesting observations were made during this three-day investigation. First, a dosage of 4 mg/l of a cationic polymeric coagulant did act as a primary coagulant and did reduce BOD_5 by approximately 40% (from 7.2-4.0 mg/l). Turbidity was reduced 75% from 16-4 JTU. However, two disadvantages were quickly apparent; within two hours, the media filter was plugging and headloss was increasing rapidly. After two and one-half hours, the pilot filter was inoperable and was completely plugged with a jelly-like floc. Indications were this floc would be almost impossible to dry as sludge on a conventional sand bed.

The second observation was that while only 4 mg/l of cationic polymeric coagulant gave significant BOD_5 and turbidity removals, others at up to 50 mg/l, with and without 0.5 mg/l non-ionic polymeric filter aid chemicals, effected little or no such removals. The third significant observation was that 100 mg/l alum with 0.05 mg/l of a non-ionic polymeric coagulant aid gave best BOD_5 and turbidity reductions, 60% (from 7.4-3.2 mg/l) and 80%(from 14 to 3 JTU), respectively. Although a large floc rapidly built up and blinded the pilot media filter, this floc was not nearly so gelatinous as the floc produced by a cationic polymeric primary coagulant.

The most significant of all was that this 2-gpm pilot media filter had demonstrated that a dynamic pressure multimedia filter was capable of efficient pollutant removals despite the very short time chemicals were in intimate contact in the wastewater stream going into the filters. The next step was to demonstrate significant increases in pollutant and color removals in the full-scale multimedia filtration plant.

Multimedia Filter Operation 3 MGD Scale

Laboratory studies using the 2-gpm pilot media filter showed that 100-150 mg/l alum or 75-125 mg/l alum plus a small amount of polymeric coagulant aids did effect very large reductions of BOD_5, COD, TOC and color from this particular wastewater after secondary treatment. Some pin-floc had been observed at 35-50 mg/l alum; this was encouraging toward reducing alum feed to the full-scale multimedia filters. Communications with several equipment suppliers, knowledgeable in wastewater treatment, indicated multimedia filtration of this secondary-clarified wastewater would not be satisfactorily accomplished on a full-scale operational basis using alum as a primary coagulant, primarily because of the effect on extended aeration activated sludge treatment lagoons and the lack of storage and handling of filter backwash water. Initial dosages of 50-150 mg/l liquid alum ahead of the multimedia filters produced a very unsatisfactory condition. This condition was characterized by a heavy, yellow skum which covered the aeration lagoons and also by a larger volume of pin-floc which was not removed in secondary-clarification and which quickly increased solids loading and shortened filter runs on the multimedia filters. It was obvious that the successful continuing operation of the biological treatment system with chemical treatment, using liquid alum addition for more efficient coagulation ahead of multimedia filtration, would be dependent on (1) reducing the amount of alum or (2) preparing an alternate and relatively expensive way of handling multimedia filter backwashes and the resulting high volume of heavy chemical (alum) sludge.

Multimedia filter backwashes were returned to the equalization tank at the head of the biological treatment plant. Excessively high alum dosages ahead of the filters upset the biological system by several actions, namely (1) increased ionic concentrations in the waste, (2) increased alum sludge "filter fines", (3) increased skum on aeration lagoons, (4) increased hydraulic loading on the secondary clarifiers, and (5) increased mixed liquor suspended solids concentration which further reduced treatment efficiency.

Through further in-practice experiments, it was determined that liquid alum dosages should best be kept at 5-10 mg/l in order not to create unnecessary biological system upsets. This was an example of not being able to carry out in a full-scale production operation what was found in the laboratory to be a viable way of significantly reducing such effluent parameters as BOD_5, COD, TOC, suspended solids and color. It also signaled the requirement for a tremendous color removal requirement in the pilot wastewater reuse study. Residual color was the largest single obstacle to the reuse of this particular wastewater in the dyeing and finishing operations.

The chemical addition locations are shown in Figure 5. Note that all chemicals were pumped directly into the wastewater influent line to the filters. The in-line turbulence of the influent wastewater, under pressure from the pumps, provided the needed mixing and chemical dilution and enhanced rapid contact between added chemicals and suspended particles in the wastewater. For a total flow of approximately 2,000 gpm to three filters in operation at approximately 700 gpm per filter, the in-line contact time for chemicals was approximately 6.3 seconds to the first filter, and approximately 16 seconds to the fourth filter. This very short contact time was demonstrated to be adequate for coagulation to take place. Contact time for chemicals used in laboratory experiments was usually 15-30 minutes; however, contact times as long as four hours were used on some investigations. The longer contact times made no discernable difference. Evaluation and experimentation led to the liquid alum/polymeric coagulant aid/powdered activated carbon slurry combinations shown in Table 24. Other evaluations were conducted, but were not included where dosages varied up to 35 mg/l alum, 2 mg/l polymer, and 30 mg/l PAC. Chemical feed rates of alum were increased during periods of poor secondary clarifier efficiency.

Average pounds per day of BOD_5, COD and suspended solids as well as Pt-Co units of color computed as monthly averages have been shown in Table 22. These removals by physical/chemical means are compared in Table 23 to removals by physical means.

Pollutant and color removal percent efficiency have been shown in Table 24. The tremendous range in percent removals from month to month resulted from physical/chemical process efficiencies which were at least in part dependent on secondary clarifier efficiency and the nature of the waste. Secondary clarifier efficiency has previously been characterized as dependent on such influences as weather, operator attention, nature of waste, design, etc.

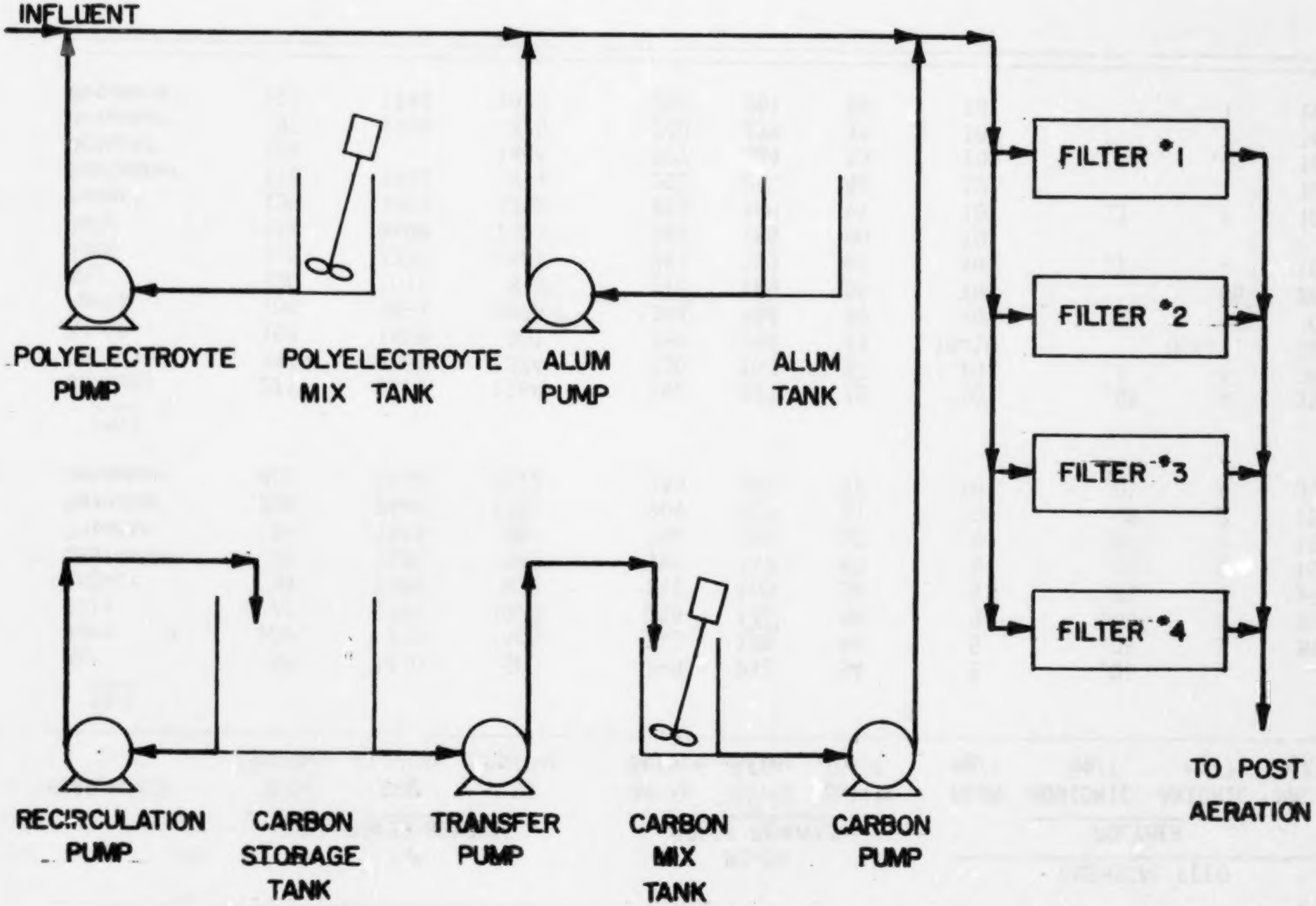

INFLUENT
POLYELECTROYTE PUMP
POLYELECTROYTE MIX TANK
ALUM PUMP
ALUM TANK
FILTER *1
FILTER *2
FILTER *3
FILTER *4
TO POST AERATION
RECIRCULATION PUMP
CARBON STORAGE TANK
TRANSFER PUMP
CARBON MIX TANK
CARBON PUMP

Figure 5. Chemical addition points.

TABLE 22. POUNDS PER DAY POLLUTANTS PLUS AMOUNTS OF COLOR REMOVED VIA MULTIMEDIA FILTRATION (TERITARY TREATMENT) WITH CHEMICAL ADDITION

YEAR/MONTH	POLLUTANTS REMOVED			Pt-Co COLOR REMOVED			CHEMICAL FEED			
								POLYMER		
	BOD_5 Lbs/Day	COD Lbs/Day	SS Lbs/Day	Units Before	Units After	Units Total	ALUM mg/1	NONIONIC mg/1	ANIONIC mg/1	PAC mg/1
1975										
May	86	1410	580	269	215	54	5	.05	-	-
June	106	817	406	233	189	44	5	.05	2	36
July	77	1387	1028	234	146	88	5	.05	2	36
August	83	1705	879	219	160	59	5	.05	2	36
September	72	1546	995	195	152	43	5	.05	2	15
October	84	1505	509	196	159	37	5	.05	2	15
November	236	2464	1363	204	153	51	5	.05	2	15
December	403	3738	2412	243	165	78	10	.05	4	35
1976										
January	271	3310	1184	255	183	72	10	.05	4	35
February	240	2965	1324	220	163	57	10	.1	4	35
March	169	1668	901	252	209	43	10-15		0.1-1.	35
April	164	1856	1073	244	204	40	10		.1	0
May	138	1635	818	215	165	50	10		.05	25
June	150	2375	1481	261	193	68	10	.1	-	10
July	112	2509	1290	265	185	80	10			
August	109	1865	1352	249	198	51	10	.1	.1	10
September	110	1522	871	263	215	48	10		.1	10
October	134		1464	277	224	53	10		.1	10
November	95	1728	879	248	229	19	10		.1	10
December	111	1748	1013	257	201	56	10		.1	10

Likewise, these same things as well as backwash cycle and concentrations/ratios of chemicals affect multimedia filter performance.

TABLE 23. INCREASED COLOR & POLLUTANT REMOVALS IN RESPONSE TO CHEMICAL ADDITIONS

	Average Lbs/Day* Removed By Physical Treatment	Avg. Lbs/Day Removed By Physical/Chemical Treatment	Percent Increased Removal By Chemical Additions
BOD_5	91	148	63%
COD	1,270	1,888	49%
S Solids	671	1,091	63%
Color	41	55	34%

*Except color, measured in Pt-Co Units.

In Table 24, chemical dosages during the first eight months were characterized by 5 mg/1 alum, very small amounts of nonionic filter aid, 2 mg/1 anionic polymeric coagulant aid and 15 to 35 mg/1 of powdered activated carbon. During the remaining twelve months, chemical dosages were primarily 10 mg/1 alum, very small amounts of each polymer type and usually 10 mg/1 PAC. In Table 25, the differences in percent removals have been shown as a function of chemical dosages.

TABLE 25. FILTER EFFICIENCIES AS A FUNCTION OF DIFFERENT FEED RATES

	mg/1 Alum	mg/1 Nonionic	mg/1 Anionic	mg/1 Carbon	Percent Removals			
					BOD_5	COD	SS	Color
8-Months	5	.05	2	15-36	47.0	25.5	80.7	25.2
12-Months	10	0-0.1	0.1	10-35	53.9	30.7	86.8	21.3

The data given in Table 25 showed three important trends, namely: (1) increased alum dosages resulted in noticeably more BOD_5, COD and suspended

TABLE 24. EFFICIENCY OF MULTIMEDIA FILTRATION - WITH CHEMICAL ADDITION

PARAMETERS	AFTER SECONDARY BIOLOGICAL TREATMENT				AFTER MULTIMEDIA FILTRATION					PERCENT REMOVED BY MULTIMEDIA FILTRATION				CHEMICAL FEED			
															POLYMER		
YEAR/MONTH	BOD$_5$ mg/l	COD mg/l	SS mg/l	Pt-Co COLOR Units	BOD$_5$ mg/l	COD mg/l	SS mg/l	TOC mg/l	Pt-Co COLOR Units	BOD$_5$ mg/l	COD mg/l	SS mg/l	Pt-Co COLOR Units	ALUM mg/l	NONIONIC mg/l	ANIONIC mg/l	PAC mg/l
1975																	
May	11.3	287	39.5	269	7.3	224	13.3	82	215	35.4	22.0	66.3	20.1	5	.05	-	-
June	10.7	224	27.3	233	5.9	187	8.9	79	189	44.9	16.5	67.4	18.9	5	.05	2	36
July	8.8	229	52.5	234	5.6	171	9.5	59	146	36.4	25.3	81.9	37.6	5	.05	2	36
August	7.8	238	43.0	219	4.3	166	5.9	59	160	44.8	30.2	86.3	26.9	5	.05	2	36
September	6.1	209	44.7	195	3.3	149	6.1	55	152	45.9	28.7	86.4	22.1	5	.05	2	15
October	7.8	231	26.8	196	4.3	168	5.5	61	159	44.9	27.3	79.7	18.9	5	.05	2	15
November	16.1	302	64.0	204	6.2	199	7.0	58	153	61.3	34.1	89.1	25.0	5	.05	2	15
December	26.3	386	111.0	243	9.9	234	12.9	89	165	62.2	39.4	88.4	32.1	10	.05	4	35
1976																	
January	21.8	384	57.3	255	10.5	246	7.9	91	183	51.8	35.9	86.2	28.2	10	.05	4	35
February	15.7	321	61.8	220	6.0	201	8.2	73	163	61.8	37.4	86.7	25.9	10	.1	4	35
March	13.0	292	43.2	252	5.9	222	5.4	80	209	54.6	24.0	87.5	17.1	10-15		0.1-1.	35
April	14.1	297	53.0	244	7.2	218	7.9	71	204	48.9	26.6	85.1	16.4	10		0.10	0
May	9.9	294	41.0	215	4.0	224	6.0	130	165	59.6	23.8	85.4	23.3	10	-	0.05	25
June	10.4	283	71.3	261	3.7	177	5.2	90	193	64.4	37.5	92.7	26.1	10	0.1	-	10
July	9.6	280	60.0	265	4.9	175	6.0	100	185	49.0	37.5	90.0	30.0	10			
August	9.8	243	74.0	249	4.6	154	9.5	55	198	53.1	36.6	87.2	20.5	10	0.1	0.1	10
September	8.3	231	45.0	263	3.4	163	6.1	61	215	59.0	29.4	86.4	18.3	10		0.1	10
October	10.3	-	78.3	277	4.0	-	9.9	63	224	61.2	-	87.4	19.7	10		0.1	10
November	10.2	316	49.0	248	5.7	234	7.3	64	229	44.1	25.9	85.1	7.7	10		0.1	10
December	12.6	330	54.6	257	7.7	253	10.0	70	201	38.9	23.3	81.7	21.8	10		0.1	10

solids removals; (2) more color removal was effected by the higher powdered activated carbon dosages; and (3) excellent removals of BOD_5, COD, suspended solids and color removals were obtained by reasonably small amounts of chemicals confirmed by results from Table 23.

One of the reasons for adding chemicals ahead of the multimedia filters was to demonstrate that average daily National Pollutant Discharge Elimination System Permit requirements for all stages could be met. Data for a twenty-month period when these particular evaluations were carried out has been shown in Table 26. All first stage requirements were met except for ammonia during a two-month period; it was felt that this was strictly an analytical problem since no other data approached violation status and there should not have been any ammonia present in the effluent from such an oxidation treatment system with greater than two-days detention time where nitrification had been previously shown to take place. All second stage requirements were met except for BOD_5 during December and January. Both months were characterized by periods of extremely cold weather, and during both months permit requirements were met on the majority of days. Scattered daily violations, particularly the two days following Christmas vacation when the manufacturing plants did not operate for a nine-day period, were responsible for this. This underscores earlier statements to the effect that (1) multimedia filter efficiency was directly linked to secondary clarifier efficiency and (2) a build-up of a very fine suspended solids in the biological system, as did happen over the nine-day vacation period, hampered efficiency and caused increased BOD_5 levels in the effluent.

The third stage permit requirements which must be met in the future are subject to some further discussion. Average daily permit requirements for TKN were not met during seven of the twenty months in this segment of the study period. Effluent TKN requirements for the third stage were set seventy-one percent lower (285 to 83 lbs/day) than for the first and second stage requirements. It was thought that TKN in the final effluent was sufficiently refractory (biologically inactive) to assure that no significant deleterious effects would occur in the receiving streams as a result of the discharge. The final effluent contained approximately 200 Pt-Co Units of color; virtually every dye used in both manufacturing plants contained organic Nitrogen.

TABLE 26. AVERAGE POUNDS PER DAY POLLUTANTS REMAINING IN FINAL EFFLUENT AFTER PHYSICAL/CHEMICAL TREATMENT VIA MULTIMEDIA FILTRATION WITH CHEMICAL ADDITION COMPARED TO THREE-STAGE NPDES PERMIT REQUIREMENTS

YEAR/MONTH	BOD_5	SUSPENDED SOLIDS	TKN	T. PHOS.	T. CHROMIUM	T. ZINC	AMMONIA	ANTIMONY	COPPER	PHENOLS	COLOR (Pt-Co)
1975											
May	159	294	117	150	0.7	8.5	6.6	11.1	0.8	4.7	215
June	130	196	119	119	0.7	5.7	6.6	11.0	0.8	2.4	189
July	134	227	103	170	0.7	5.4	11.9	23.9	1.5	3.2	146
Aug	102	140	76	121	0.7	2.0	9.4	29.6	1.3	2.1	160
Sept	84	157	64	155	0.8	3.2	9.8	25.8	4.5	1.6	152
Oct	103	131	67	93	1.0	2.2	11.9	17.9	1.5	2.2	159
Nov	148	167	79	91	0.7	2.4	12.0	28.7	1.3	2.9	153
Dec	243	273	108	121	0.7	4.6	9.8	12.3	0.7	1.6	165
1976											
Jan	252	189	142	86	0.7	3.5	7.2	24.0	1.0	3.0	183
Feb	148	203	72	114	0.7	3.1	7.4	21.0	1.3	2.3	163
Mar	141	129	57	148	0.8	4.3	14.3	17.0	1.4	1.9	209
Apr	171	193	164	164	0.8	3.2	30.9	29.7	2.1	1.6	204
May	109	147	58	182	0.7	2.0	30.4	22.6	2.3	1.5	182
June	83	117	105	141	0.8	4.7	17.9	26.9	2.0	2.8	193
July	117	143	57	184	0.8	5.3	9.5	22.7	2.2	1.2	187
Aug	96	199	57	191	0.9	1.8	6.3	30.4	2.3	1.2	198
Sept	76	137	58	183	0.8	2.9	6.7	17.9	2.8	0.2	217
Oct	86	212	64	161	0.7	2.2	7.7	10.7	2.1	0.2	224
Nov	120	154	72	148	0.6	1.8	6.3	29.5	2.5	0.7	229
Dec	175	227	57	136	0.9	3.1	6.8	18.0	2.9	0.2	201
AVG.	134	182	85	143	0.8	3.6	11.5	21.5	1.9	1.8	186

NPDES Permit Effluent Requirements: Stage 1 was 12/73-6/75; Stage 2 was 7/75-6/78; Stage 3 was 7/78-12/78.

Stage											
1	375	1,013	285	225	4.7	21.0	19	79	5.0	9.6	-
2	210	417	285	225	4.8	21.0	46	79	6.7	9.6	-
3	210	417	*83	225	2.0	12.5	46	21	0.8	4.0	-

*TKN may be higher provided permittee can show no deleterious effects on stream biota and water quality.

Furthermore, a tremendous number of chemicals used in normal dyeing and finishing in the textile industry contain organic Nitrogen. A thirty-day long term aeration study was made comparing (a) 100% final effluent wastewater and (b) 75% final effluent wastewater with 25% made up of water taken upstream of the plant discharge. Results of these two parallel studies have been shown in part in Table 27. The final effluent was found almost completely refractory and presented evidence for modification negotiations with regulatory agencies.

TABLE 27. LONG TERM AERATION EFFECT ON TKN IN FINAL EFFLUENT

Days Aerated	BOD_5 (mg/l)		COD (mg/l)		TOC (mg/l)		TKN (mg/l)	
	A	B	A	B	A	B	A	B
0	3.5	2.6	184	142	59	46	2.6	1.8
11	2.9	2.0	165	141	51	38	2.3	1.8
20	1.4	1.4	157	137	39	34	2.2	1.7
30	1.6	1.8	157	135	40	32	2.3	1.8

Sample A = 100% Final Effluent Wastewater
Sample B = 75% Final Effluent Wastewater/25% Upstream Water

It was noted that the COD/BOD_5 ratio for both Samples A and B exceeded fifty, which indicated a well biologically treated industrial effluent. It was doubtful whether longer aeration time would have caused significant changes.

The major problem with meeting third stage NPDES Permit requirements was shown to be removal of Antimony and Copper (heavy metals). The Antimony resulted from a dye fixative for certain acid dyes needed to meet customer's end use colorfastness requirements for certain shades. Alternate after-fixing methods, as well as color reformulations, were suggested and placed under investigation. The Copper also resulted from meeting customer's specific end-use colorfastness requirements for certain colors. Alternate methods of treatment as well as reformulations were suggested and placed under investigation in order to reduce the Copper content in the final effluent.

The single instance of not meeting phenol requirements was thought to be due to analytical difficulties because this parameter's requirement was met during the remaining nineteen months of this study segment.

A particle size distribution and particle count is provided in Table 28 where secondary clarifier (biological) effluent was compared with multimedia filter effluent (final effluent). In each instance approximately three-fourths of the particles were 2.5 microns or smaller. It was interesting to note that there were approximately seventy percent fewer particles in the multimedia filter effluent. These particle counts substantiate turbidity readings and visual checks made in-plant which show a very clear, though colored, final effluent.

The multimedia filter, with and without chemical feeds, has been demonstrated to be a viable advanced wastewater treatment technique for biologically treated, secondary-clarified, chlorinated wastewater from plants dyeing and finishing fabrics knitted from man-made fibers. There is no readily apparent reason why this technology cannot be applied to secondary wastewaters from plants dyeing and finishing fabrics manufactured from man-made fibers or dyeing and finishing these same yarns in accepted yarn and/or fabric forms. Small amounts of one or more coagulant chemicals, which may be complemented by powdered activated carbon addition, has been demonstrated to further reduce organic pollutant and residual color levels in secondary wastewater. The success of this technology remains tied to the quality of wastewater influent, the nature of the wastes being treated, and responsible wastewater treatment plant operation.

The application of the multimedia filtration technique with supplemental chemical additions has been shown to provide a very high quality effluent which has met very stringent NPDES Permit requirements designed to protect extremely small streams used for navigation, fish and wildlife propagation and recreation.

The somewhat less successful color removal cannot be considered a failure because of the nature of the colored compounds in the wastewater. The presence of residual color in this particular multimedia filter effluent made it very difficult to treat to a quality satisfactory for dyeing and finishing reuse.

TABLE 28. PARTICLE SIZE DISTRIBUTION

SIZE RANGE	PERCENT	APPROXIMATE NUMBER/ML
SAMPLE: SECONDARY CLARIFIER EFFLUENT		
<1.25 u	29.7	4.60×10^6
1.25 - 2.5	54.2	8.40×10^6
2.5 - 5.0	7.2	1.12×10^6
5.0 - 7.5	3.6	0.56×10^6
7.5 - 12.5	1.6	0.25×10^6
12.5 - 25	2.0	0.31×10^6
>25 u	1.2	0.19×10^6
TOTAL	99.5	15.5×10^6
SAMPLE: MULTIMEDIA FILTER EFFLUENT		
<1.25 u	23.5	1.45×10^6
1.25 - 2.5	50.0	2.25×10^6
2.5 - 5.0	21.0	0.93×10^6
5.0 - 7.5	2.2	0.098×10^6
7.5 - 12.5	--	--
12.5 - 25	--	--
>25 u		
TOTAL	96.7	4.45×10^6

SAMPLES TAKEN 6/8/76: PRESERVED WITH MERTHIOLATE

Should very stringent color requirements be imposed, then other means of removal demonstrated in the pilot water reuse study of this project would have to be applied. The cost of doing so would be very high.

An expanded table showning NPDES discharge requirements has been provided in Table 29. A three-month monitoring report has also been compared to these NPDES requirements in Table 29.

TABLE 29. NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM DISCHARGE MONITORING REPORT

PARAMETERS	PERMIT CONDITIONS IN POUNDS PER DAY		POUNDS PER DAY		
	AVERAGE	MAXIMUM	MINIMUM	AVERAGE	MAXIMUM
BOD_5	210	320	0.0	96.9	195.2
Total Suspended Solids	417	689	11.2	150.5	329.0
Total Kjeldahl Nitrogen	285	398	38.8	80.7	180.2
Ammonia	46	92	4.8	12.8	33.5
Total Phosphorus	225	469	19.1	175.9	283.6
Total Chromium	4.7	8.6	0.71	0.84	1.41
Total Zinc	21	41	0.97	3.99	7.52
Antimony	79	113	22.4	27.6	38.0
Total Copper	6.7	9.6	1.45	2.03	3.09
Phenols	9.6	75	0.89	1.50	2.47
Flow (MGD*)	5.0*	5.5*	0.000*	2.624*	3.160*
pH (Units*)	6.0-8.5*		6.9*		7.5*

Permit Reporting Period: June 1, 1976 through August 31, 1976.

* Units as shown - not pounds

SECTION 7

WATER REUSE - PILOT STUDY

The second major objective of this project was to determine whether dyeing and finishing wastewater, which had been treated biologically and by physical/chemical means, via multimedia filtration with chemical addition, could be further treated to a quality suitable for dyeing and finishing reuse. The pilot study was carried out using two approaches. The first was a mobile trailer equipped with chemical treatment to coagulate color and other pollutants, settle it to remove the greater portion of the heavy chemical sludge and filter the clarifier supernatant for greatly improved removals. The second was a 5-column train consisting of columns charged with sand, powdered active carbon, organic scavenging resin, cation ion-exchange resin, and anion ion-exchange resin. Wastewater treated via this entire scheme was evaluated in the laboratory to determine its suitability for reuse in the dyeing and finishing of man-made fiber fabrics. The equipment, its operation and results, are described in the following.

THE MOBILE PILOT PLANT

The mobile pilot plant was a wastewater treatment plant consisting of a chemical coagulation chamber, chemical addition equipment, twin flocculator tanks, horizontal parallel tube clarifier, and mixed media filter. This unit, hereinafter referred to as the MPP (mobile pilot plant), was used to chemically coagulate the majority of the color and other pollutants present in this particular wastewater. The reduced color/pollutant load in the MPP effluent was further treated to remove most of the remaining color, organics, and heavy metals.

The MPP coagulation system consisted of an influent line outfitted with an adjustable flow control valve, a soleniod valve which closed the influent line during backwashing, and provisions for the simultaneous injection of up to four different chemicals. Four 12-gallon chemical mixing tanks and four chemical feed pumps were provided for these chemical additions. A 1/30 Hp mixer was provided for mixing the chemical solutions. The coagulation system also consisted of a rapid-mix tank which provided a rapid-mix time of one minute at the maximum flow rate of 10 gpm by means of a 1/3 Hp mixer. The wastewater gravity flowed into the first of two flocculator tanks. The first flocculator was equipped with a flocculation paddle driven by a 1/12 Hp gear motor at 6 RPM. The second flocculator was equipped with a flocculator paddle driven by a 1/12 Hp gear motor at 2 RPM. The detention time in each of these tanks was ten minutes at the maximum flow rate of 10 gpm. The piping to this system was such that the first flocculation compartment could be by-passed by simply closing the valve to the first compartment and then opening the valve to the second compartment which allowed the wastewater from the rapid mix tank to flow directly into the second flocculator tank.

The clarifier flow was from the second flocculator tank only, irrespective of whether one or both had been used. This system consisted of a settling tank with parallel, 7 1/2^{0} from horizontal, hexagonal, one-inch settling tubes thirty-nine inches long. Detention time was twenty-five minutes with a tube loading rate of 1.67 gpm/sq.ft. The flow from the clarifier was then filtered through a two square-foot surface area single-media filter. The design flow rate for the filter was five gpm/sq.ft. The design backwash rate was 17 gpm/sq.ft. with a fixed surface wash rate of two gpm/sq.ft. The filter was set to automatically backwash at a headloss of seven feet, but a backwash could also be initiated manually by an "initiate" button on the control panel.

Pilot plant flow rate was controlled by the adjustable flow control valve in the influent line and matched with a float valve above the filter. The flow rate was indicated by a flow meter in the effluent line. The backwash flow rate was controlled and set by means of an adjustable flow control valve provided in the backwash line.

The Mobile Pilot Plant Operating Procedure

The influent to the MPP unit was the final effluent wastewater which was diverted for further treatment instead of discharged directly to the receiving stream. This dyeing and finishing wastewater had been biologically treated, secondary clarified, chlorinated and treated through the multimedia filter plant as previously described. This water was taken from a chlorinator feed water line under pump pressure ahead of the chlorinator; a tee and solenoid valve provided a water supply under pressure without need of a supplementary sump and/or pump. The flash mix tank was not used because of a foaming problem which developed when high alum dosages were used. Water and injected chemicals were added in the first flocculator where initial flocculation took place under slight agitation from the 6 RPM stirrer. Secondary flocculator effluent, after slow mixing, was gravity fed into the horizontal tube clarifier where the heavier, rapidly settling solids were removed. The supernatant was filtered through the single media filter to remove most suspended matter. The single media filter was backwashed when floc carryover was easily visible. This usually occurred at a headloss of approximately four feet. The backwash was initiated manually but operated by an analog controller. Backwash water used was effluent from the MPP which had been stored in a three-hundred gallon tank. Backwash rate was thirty-four gpm and controlled with the backwash flow control valve. During each backwash, the tube clarifier was drained to remove solids and then refilled with backwash water during the last part of the backwash cycle. The tube clarifier was drained because it was the only means of wasting the settled sludge and the backwash water from the filter. Wastewater treated in this manner had greatly reduced amounts of color and pollutant levels. It was then piped to the second phase of pilot treatment, the 5-column train.

FIVE-COLUMN PILOT WATER TREATMENT PLANT

The final effluent from the MPP was given further treatment in the 5-column train. This pilot treatment plant consisted of five pressure columns with a decarbonator incorporated between the cation and anion columns. Flow through the plant was measured by a 5/8 inch bronze meter; flow rate was monitored by a ball check valve. Influent to this portion of the pilot plant was provided by a 3/4 Hp deep well water pump. Dimensions of the five fiberglass columns were 9-5/8" I.D. x 4 feet 9-5/16 inches high. Each column was equipped with two 0-100 psi pressure gauges for measuring inlet and outlet pressure and to indicate the pressure loss across the beds. Refer to Table 30 for design parameters for this 1.5 gpm 5-column pilot water treatment plant. Piping was arranged so that the full 1.5 gpm influent (from the MPP) could be directed individually to each of the columns except the anion exchanger. It was necessary for influent to the anion exchanger to first have been treated through the cation exchanger and the decarbonator. Removal of carbon dioxide by the decarbonator was necessary so that anion exchanger efficiency could be kept high. Sand and carbon columns were only backwashed for physical removal of entrapped solids. The remaining three columns required both backwashing for physical removal and chemical regeneration. Note that backwash flow rates were varied for each of the columns. Sand filtration was for protection against suspended solids fouling of the remaining columns' media. No appreciable color or pollutant removals were obtained, as this installation served only as a protection for other units. Carbon served as an adsorption and absorption media. Its use has been well documented. The organic scavenging resin was evaluated to determine what effect it had on color removal first and on organic pollutants second. The cation and anion exchangers were for final polishing by removing charged color particles, metals known to affect dyeing and finishing, and other charged molecules which were removable.

Filter Backwash & Operations Sequence

Table 30 provides information on backwash and regeneration requirements for all units. The sand filter was backwashed using pilot plant effluent whenever headloss reached 8 psi or at least once per week. The carbon column was backwashed with sand filter effluent whenever headloss reached 4 psi. The organic trap resin was backwashed and regenerated using carbon column effluent. The cation exchanger was backwashed and regenerated using carbon filter effluent when effluent pH increased by 0.2 - 0.3 pH units. The anion exchanger was backwashed and regenerated with the cation exchanger effluent. During the upflow backwashing, resin loss was a problem which had to be controlled by operator monitored backwash rate. Visual examination was made and flow rate was controlled to prevent resin loss. The operation and backwash/regeneration operations of this pilot plant were extremely involved and time consuming. It was necessary for an operator to remain with the equipment

TABLE 3Q DESIGN DATA FOR 1.5 GPM FIVE-COLUMN PILOT WATER TREATMENT PLANT

EQUIPMENT	SAND FILTER	CARBON FILTER	ORGANIC TRAP	CATION EXCHANGER	DECARBONATOR	ANION EXCHANGER
No. Units	1	1	1	1	1	1
Màx. Influent	1.5 GPM	1.5 GPM	1.5 GPM	1.5 GPM	1.5 GPM	1.5 GPM
Max. Effluent	1.5 GPM	1.5 GPM	1.5 GPM	1.5 GPM	1.5 GPM	1.5 GPM
Media Type	.45-.50 mm Filter Sand	20 X 50 mesh Activated Carbon	Dowex 11	Invercarb C-110	-	Invercarb A-200
Media Support 0.6 - 0.8 mm Filter Sand	4"	4"	4"	4"	None	4"
Volume of Media (Cu.Ft.)	1.5	1.5	1.3	1.3	-	1.3
Depth of Media (Inches)	36"	36"	32"	32"	-	32"
Diameter of Column (In.)	9 5/8"	9 5/8"	9 5/8"	9 5/8"	12"	9 5/8"
Height of Column (In.)	57 5/16"	57 5/16"	57 5/16"	57 5/16"	48"	57 5/16"
Regeneration or Backwash	Backwash	Backwash	Backwash & Regeneration	Backwash & Regeneration	-	Backwash & Regeneration
Backwash Rate (GPM)	6	1.5	1.0	3.0	-	1.0

(Continued)

TABLE 30. (Continued)

EQUIPMENT	SAND FILTER	CARBON FILTER	ORGANIC TRAP	CATION EXCHANGER	DECARBON-ATOR	ANION EXCHANGER
Backwash Water Source	MPP Effluent	Sand Filter	Carbon Filter	Organic Trap	-	Cation Exchanger
Regenerant	-	-	NaCl/NaOH	HCl	-	Soda Ash
% Solution of Regenerant	-	NaCl 40% -	NaOH 4.0%	30%	-	12%
Lbs. Regenerant/ Regeneration	-	-	NcCl 7.5 lbs. NaOH .75 lbs.	26 lbs.	-	5 lbs.

NaCl = Sodium Chloride

NaOH = Sodium Hydroxide

HCl = Hydrochloric Acid

through the entire backwash sequence. Any scale-up of this equipment should be equipped with automatic flow controls and sufficient monitoring equipment to insure adequate backwashing and complete chemical regeneration.

EVALUATION OF PILOT PLANT EFFLUENT WATER QUALITY

Color Removal

Color was measured as apparent color with a Hellige glass color disc and expressed as Pt-Co units of color. Extensive color measurements were made from influent wastewater from manufacturing through final effluent from the pilot plant. Table 31 provides some of the extensive color measurements made throughout the entire process.

Color removal between full scale wastewater treatment plant influent and effluent was approximately 55%, with a residual color of approximately 200 units remaining to be removed by the pilot treatment processes.

The MPP effected various removals dependent upon the amount of alum or alum/polymer used for coagulation. It should be noted that approximately eighty percent of the total dye used in both plants was disperse dye; consequently coagulation was demonstrated to be effective as a removal mechanism for large amounts of color. Soluble color had to be removed by ion exchange resins in the organic trap, cation and anion exchangers of the pilot units. It should be noted that through the MPP, approximately 7-20% color was removed when 100 mg/l alum was used along with varying dosages of polymeric coagulant aid. However, when alum dosages were increased, color removal was also increased. At 200 mg/l alum, some 29-40% color was removed; at 250 mg/l alum, 20-80% color was removed; and at 350 mg/l alum, 71-62% color was removed. At 350 mg/l alum, consistently higher amounts of color were removed.

Average color removal across the 5-column wastewater treatment pilot unit was approximately ninety percent. The sand filter removed essentially no color, as was expected. The activated carbon filter exhibited a continuing reduction in color removal efficiency with continuing throughput. Mid-way through the project, color removals of 60-80 Pt-Co units could be obtained; however, with new carbon, color removals up to 110 Pt-Co units were obtained. Carbon in the column was replaced part-way through the project. The organic

TABLE 31. EVALUATION OF COLOR REMOVAL FROM TEXTILE WASTEWATER

PRESENT WASTEWATER TREATMENT PROCESS						WATER REUSE PROJECT							
		CHEMICAL FEED RATES AHEAD OF MULTIMEDIA FILTERS				MPP CHEMICAL FEED RATES		EFFLUENT FROM					
UNTREATED MANUFACTURING WASTE	BIOLOGICALLY TREATED WASTE	ALUM	POLYMER	P A C	FINAL EFFLUENT	ALUM	POLYMER	MOBILE PILOT PLANT	SAND FILTER	CARBON FILTER	ORGANIC TRAP	CATION EXCHANGER	ANION EXCHANGER
Units Pt-Co	Units Pt-Co	mg/l	mg/l	mg/l	Units Pt-Co	mg/l	mg/l	Units Pt-Co	Units Pt-Co	Units Pt-Co	Units Pt-Co	Units Pt-Co	Units Pt-Co
500	200	10	0.1	35	125	250		65	60	15	<10	2	<2
500	200	10	0.1	35	175	250		70	50	5	<5	<2	<2
400	200	10	0.1	35	175	250		35	35	8	5	<5	<2
500	175	10	0.1	35	150	250		70	65	10	8	<2	<2
350	175	10	0.1	35	125	250		80	70	25	25	20	18
400	225	10	0.1	35	175	250		100	100	35	25	15	2
800	250	10	0.1	35	225	250		125	100	70	50	25	7
300	275	15	0.5	35	250	250		140	140	70	55	2	2
500	225	15	0.5	35	200	250		80					
400	275	10	0.25	35	225	250		160	140	90	80	55	25
500	300	10	0.25	35	250	250		65	65	12	<5	<2	<2
600	250	10	0.25	35	175	250		100	100	45	35	25	7
400	225	10	0.25	35	200	250		70	70	20	15	7	5
400	200	10	0.25	35	175	250		70	70	15	7	7	5
300	175	10	0.10	35	175	250		80	70	25	20	15	15

(Continued)

TABLE 31. (CONTINUED)

PRESENT WASTEWATER TREATMENT PROCESS						WATER REUSE PROJECT								
		CHEMICAL FEED RATES AHEAD OF MULTIMEDIA FILTERS				MPP CHEMICAL FEED RATES		EFFLUENT FROM						
UNTREATED MANUFACTURING WASTE	BIOLOGICALLY TREATED WASTE	ALUM	POLYMER	P A C	FINAL EFFLUENT	ALUM	POLYMER	MOBILE PILOT PLANT	SAND FILTER	CARBON FILTER	ORGANIC TRAP	CATION EXCHANGER	ANION EXCHANGER
Units Pt-Co	Units Pt-Co	mg/1	mg/1	mg/1	Units Pt-Co	mg/1	mg/1	Units Pt-Co	Units Pt-Co	Units Pt-Co	Units Pt-Co	units Pt-Co	Units Pt-Co
400	225	10	0.10	15	200	250		130	130	70	70	50	17
400	225	10	0.10	15	175	250		90	90	45	45	40	20
400	225	10	0.10	-	200	250		80	80	30	35	10	5
100	250	10			175	250		140	140	90	80	50	35
500	250	10			200	250		100	100	40	40	30	10
400	250	10			175			200	200	120	120	80	60
500	250	10	0.05		200	100	1	175	175	125	125	70	40
600	200	10	0.05		200	100	2	160	140	100	90	70	35
300	200	10	0.05	25	150	100	5	125					
400	175	10	0.05	25	150	100	12	140					
500	300	10	0.10	25	200	170	12	120					
400	200	10	0.05	25	175	200	12	125					
500	250	10	0.10	25	200	250	12	160					

(Continued)

TABLE 31. (CONTINUED)

PRESENT WASTEWATER TREATMENT PROCESS						WATER REUSE PROJECT							
UNTREATED MANUFACTURING WASTE	BIOLOGICALLY TREATED WASTE	CHEMICAL FEED RATES AHEAD OF MULTIMEDIA FILTERS			FINAL EFFLUENT	MPP CHEMICAL FEED RATES		EFFLUENT FROM					
		ALUM	POLYMER	P A C		ALUM	POLYMER	MOBILE PILOT PLANT	SAND FILTER	CARBON FILTER	ORGANIC TRAP	CATION EXCHANGER	ANION EXCHANGER
Units Pt-Co	Units Pt-Co	mg/1	mg/1	mg/1	Units Pt-Co	mg/1	mg/1	Units Pt-Co	Units Pt-Co	Units Pt-Co	Units Pt-Co	units Pt-Co	Units Pt-Co
500	250	10	0.10	25	200	250	12	80	80	35	35	20	8
400	300	10	0.10	10	200	250	12	150	125	70	70	45	50
800	250	10	0.10	10	200	250	12	80	80	25	25	20	35
500	250	10	0.10	10	250	150	3	160	160	45	45	25	10
700	250	10	0.10	10	200	200	3	120	120	30	30	10	5
400	200	10	0.10	10	175	200	3	140	140	50	50	30	10
300	250	10	0.10	10	200	250	3	140	140	45	45	25	7
400	275	10	0.10	10	250	250	3	100	100	10	10	5	<2
400	275	10	0.10	10	250	350	3	200	200	100	100	50	2
400	250	10	0.10	10	225	350	3	40	40	2	2	<2	<2
500	250	10	0.10	10	200	350	3	45	45	5	5	<2	<2
450	240	10	0.10	10	175	350	3	50	35	2	2	<2	<2

scavenging resin appeared to remove small amounts of color when it was first used; however, during the latter half of the project period, almost no color removal was obtained.

The cation and anion exchangers together removed virtually all the color present when influent to the cation exchanger contained less than fifty Pt-Co units of color and when large alum dosages had previously removed most dispersed color. Carbon is not effective in removing color due to dispersed materials.

This complete pilot wastewater treatment plant demonstrated that residual color could be removed from wastewater and that it could be rendered satisfactory for dyeing and finishing re-use. The fact that soluble and insoluble dyes must be removed by different mechanisms, when present in the same waste stream, was demonstrated.

pH Determinations

The pH was measured with a Beckman pH meter equipped with reference calomel and glass electrodes. The meter was standardized daily with pH 4.0 and pH 9.0 buffers. Wastewater influent to the pilot plant had a pH of 7.0 - 7.5. In the first treatment stage when up to 350 mg/l alum was used in the MPP, the pH was reduced by approximately 1.0 unit. No appreciable pH change occurred during passage through sand, carbon and organic scavenging resin filters. Effluent from the cation exchanger had a pH of 2.4 to 3.1, because of hydrogen ion exchange for metals and other multivalent substances. However, pH was increased to between 4.1 and 8.8 during passage through the anion exchanger where hydroxide was exchanged for other anionic groups. In a scale-up for a large plant, both acid and alkaline neutralization feeds would be required in order to insure uniform pH water to processing. See Table 32 for representative pH at all parts of the total wastewater system.

Turbidity

Turbidity was measured with a Hach Model 2100A Turbidimeter for all pilot plant readings. Turbidity was usually noticeably higher in the MPP effluent than the influent, because of fine alum floc carryover. This floc carryover, not removed by clarification and media filtration, was increasingly visible toward the end of the operating cycle. Turbidity removed by

TABLE 32. pH EVALUATION

PRESENT WASTEWATER TREATMENT PROCESS						WATER REUSE PROJECT							
UNTREATED MANUFACTURING WASTE	BIOLOGICALLY TREATED WASTE	CHEMICAL FEED RATES AHEAD OF MULTIMEDIA FILTERS			FINAL EFFLUENT	MPP CHEMICAL FEED RATES		EFFLUENT FROM					
		ALUM	POLYMER	P A C		ALUM	POLYMER	MOBILE PILOT PLANT	SAND FILTER	CARBON FILTER	ORGANIC TRAP	CATION EXCHANGER	ANION EXCHANGER
Units	Units	mg/1	mg/1	mg/1	Units	mg/1	mg/1	Units	Units	Units	Units	Units	Units
7.3	7.1	10	0.10	35	7.2	250		6.6	6.5	6.5	6.4	2.6	8.7
7.2	7.4	10	0.10	35	7.5	250		6.7	6.5	6.4	6.6	2.7	8.4
7.2	7.1	10	0.10	35	7.3	250		6.6	6.5	6.5	6.6	2.7	8.1
7.3	7.2	10	0.10	35	7.3	250		6.6	6.5	6.4	6.5	2.8	8.8
7.1	7.0	10	0.10	35	7.1	250		6.3	6.3	6.8	6.9	2.6	6.2
7.1	7.1	10	0.10	35	7.2	250		6.6	6.5	6.5	6.7	3.1	7.3
7.1	7.1	10	0.10	35	7.3	250		6.5	6.4	6.4	6.4	2.7	6.7
6.6	7.2	15	0.5	35	7.4	250		6.9	6.9	6.8	6.4	2.8	6.1
7.1	7.3	15	0.5	35	7.4	250		6.7	6.6	6.7	6.7	2.9	5.8
7.6	7.3	10	0.25	35	7.1	250		6.7	6.6	6.7	6.7	2.9	4.8
7.5	7.2	10	0.25	35	7.2	250		6.4	6.4	6.6	6.7	2.9	4.6
7.4	7.3	10	0.25	35	7.0	250							
7.6	7.5	10	0.25	35	7.5	250		6.7	6.5	6.6	6.6	2.9	4.6
8.8	7.3	10	0.25	35	7.3	250		6.5	6.4	6.5	6.5	2.8	4.5

(Continued)

TABLE 32. (CONTINUED)

PRESENT WASTEWATER TREATMENT PROCESS						WATER REUSE PROJECT								
		CHEMICAL FEED RATES AHEAD OF MULTIMEDIA FILTERS				MPP CHEMICAL FEED RATES		EFFLUENT FROM						
UNTREATED MANUFACTURING WASTE	BIOLOGICALLY TREATED WASTE	ALUM	POLYMER	P A C	FINAL EFFLUENT	ALUM	POLYMER	MOBILE PILOT PLANT	SAND FILTER	CARBON FILTER	ORGANIC TRAP	CATION EXCHANGER	ANION EXCHANGER
Units	Units	mg/1	mg/1	mg/1	Units	mg/1	mg/1	Units	Units	Units	Units	Units	Units
7.7	7.4	10	0.10	35	7.3	250		6.7	6.6	6.7	6.7	2.8	4.2
7.8	7.6	10	0.10	15	7.5	250		7.1	7.0	7.0	6.8	2.9	4.4
7.4	7.5	10	0.10	15	7.5	250		6.8	6.7	6.8	6.8	2.9	4.4
7.7	7.3	10	0.10		7.4	250		6.7	6.7	6.7	6.0	2.4	7.3
6.9	7.1	10			7.3	250		6.5	6.4	6.5	6.4	2.4	4.4
7.4	7.1	10			7.3	250		6.4	6.3	6.4	6.3	2.5	4.3
7.4	7.2	10			7.4			7.1	7.1	6.7	6.5	2.5	4.0
7.8	7.3	10	0.05		7.5	100	1	6.9	6.9	6.7	6.7	2.9	6.8
7.5	7.2	10	0.05		7.4	100	2	6.9	6.8	6.8	6.8	2.8	5.1
7.4	7.2	10	0.05	25	7.3	100	5						
8.0	7.1	10	0.05	25	7.2	100	12						
9.2	7.2	10	0.10	25	7.0	170	12	6.7	6.6	6.5	6.7	2.6	5.6
7.3	7.2	10	0.05	25	7.4	200	12	7.3					
8.3	7.2	10	0.10	25	7.3	250	12	7.3					

(Continued)

TABLE 32. (CONTINUED)

PRESENT WASTEWATER TREATMENT PROCESS						WATER REUSE PROJECT							
UNTREATED MANUFACTURING WASTE	BIOLOGICALLY TREATED WASTE	CHEMICAL FEED RATES AHEAD OF MULTIMEDIA FILTERS			FINAL EFFLUENT	MPP CHEMICAL FEED RATES		EFFLUENT FROM					
		ALUM	POLYMER	P A C		ALUM	POLYMER	MOBILE PILOT PLANT	SAND FILTER	CARBON FILTER	ORGANIC TRAP	CATION EXCHANGER	ANION EXCHANGER
Units	Units	mg/l	mg/l	mg/l	Units	mg/l	mg/l	Units	Units	Units	Units	Units	Units
7.3	7.1	10	0.10	25	7.3	250	12	6.3	6.5	6.5	6.8	2.5	5.5
7.4	7.2	10	0.10	10	7.4	250	12	6.7	6.6	6.6	6.8	2.5	5.5
7.1	7.2	10	0.10	10	7.4	250	12	6.8	6.6	6.7	6.9	2.5	5.5
7.5	7.2	10	0.10	10	7.3	150	3	6.4	6.4	7.3	7.0	2.5	4.3
9.2	7.3	10	0.10	10	7.4	200	3	6.3	6.7	6.6	6.7	2.9	4.3
7.4	7.3	10	0.10	10	7.1	200	3	6.9	6.7	6.8	6.9	2.7	4.8
8.5	7.2	10	0.10	10	7.3	250	3	6.4	6.4	6.4	6.3	2.7	4.6
7.5	7.4	10	0.10	10	7.5	250	3	6.5	6.4	6.4	6.3	2.8	4.6
9.3	7.4	10	0.10	10	7.1	350	3	6.9	6.8	6.7	6.7	3.1	4.7
8.5	7.3	10	0.10	10	7.3	350	3	6.5	6.4	6.4	5.8	2.8	4.3
7.5	7.4	10	0.10	10	7.4	350	3	6.6	6.5	6.5	6.5	2.8	4.6
10.3	7.3	10	0.10	10	7.5	350	3	6.5	6.3	6.4	6.6	2.8	4.1

sand, carbon and organic scavenging columns was only slight; the organic scavenging resin lost much of its turbidity removal ability during the latter half of the project.

The most significant turbidity removals were effected by the cation exchanger. It is not known whether the removal was by physical or chemical means. As more color was removed from the wastewater, the interference due to turbidimeter light beam absorption was reduced giving a more accurate reading. See Table 33 for turdibity readings throughout the entire full-scale and pilot wastewater treatment facilities.

Specific Conductivity

All specific conductivity measurements were made with a Beckman Conductivity Bridge. Since addition of salt in dyeing with direct dye colors was not common practice in these two manufacturing plants, the normal final effluent conductivity was 450 - 600 mhos with occasional readings slightly above and below this range. Conductivity increased to 600 - 800 mhos in the MPP trailer effluent due to alum treatment. This range was generally constant through sand, carbon and organic resin filter columns. However, conductivity increased to a typical 1500 - 3000 mhos when passing through the cation exchanger; this was due to increased hydrogen ion concentration. Table 34 reflects specific conductivity readings through the full-scale and pilot treatment plants. The abrupt reduction in specific conductivity of anion exchanger effluent should be noted. This indicated a high purity water was generated.

Specific conductivity was an excellent indicator of breakthrough of both the cation and anion exchangers and was employed as an operational tool. Unusually high readings in anion exchanger effluent, shown in Table 33, was the signal that caused this unit to be backwashed/regenerated.

Total Solids (TS)

Total solids were determined gravimetrically, using 100 milliliter samples. The treated wastewater effluent to the receiving stream contained approximately 500 mg/l of total solids; this water source became the influent to the pilot plant. Passage through the MPP unit generally netted a slightly

TABLE 33. TURBIDITY

PRESENT WASTEWATER TREATMENT PROCESS						WATER REUSE PROJECT							
		CHEMICAL FEED RATES AHEAD OF MULTIMEDIA FILTERS				MPP CHEMICAL FEED RATES		EFFLUENT FROM					
UNTREATED MANUFACTURING WASTE	BIOLOGICALLY TREATED WASTE	ALUM	POLYMER	P A C	FINAL EFFLUENT	ALUM	POLYMER	MOBILE PILOT PLANT	SAND FILTER	CARBON FILTER	ORGANIC TRAP	CATION EXCHANGER	ANION EXCHANGER
FTU	FTU	mg/1	mg/1	mg/1	FTU	mg/1	mg/1	FTU	FTU	FTU	FTU	FTU	FTU
71	29	10	0.10	35	5.3	250		6.3	6.0	5.9	5.0	0.44	0.16
78	28	10	0.10	35	3.8	250		3.1	2.8	2.0	1.0	0.42	0.34
60	20	10	0.10	35	3.5	250		5.0	4.4	3.7	2.5	0.69	0.37
77	21	10	0.10	35	4.7	250		6.4	5.5	4.1	3.9	0.41	0.99
79	18	10	0.10	35	4.4	250		5.8	5.2	5.3	5.2	1.4	1.9
95	16	10	0.10	35	4.1	250		3.6	3.0	3.0	2.8	1.4	0.52
60	29	10	0.10	35	7.9	250		24.0	18.0	17.0	15.0	2.3	1.3
77	20	15	0.5	35	8.0	250		13.0	12.0	12.0	10.0	0.44	0.33
66	29	15	0.5	35	9.9	250		7.9	6.4	5.9	4.8	1.3	1.5
73	40	10	0.25	35	15.0	250		21.0	17.0	17.0	15.0	7.0	2.5
67	24	10	0.25	35	8.1	250		4.5	5.0	3.7	1.9	0.37	0.45
65	17	10	0.25	35	2.5	250		7.0	7.7	8.0	6.8	0.82	0.73
61	10	10	0.25	35	2.5	250		4.5	4.0	3.8	3.5	0.52	0.61
88	15	10	0.25	35	2.4	250		3.6	3.2	2.6	2.4	0.52	0.45

(Continued)

TABLE 33. (CONTINUED)

PRESENT WASTEWATER TREATMENT PROCESS						WATER REUSE PROJECT								
		CHEMICAL FEED RATES AHEAD OF MULTIMEDIA FILTERS				MPP CHEMICAL FEED RATES		EFFLUENT FROM						
UNTREATED MANUFACTURING WASTE	BIOLOGICALLY TREATED WASTE	ALUM	POLYMER	P A C	FINAL EFFLUENT	ALUM	POLYMER	MOBILE PILOT PLANT	SAND FILTER	CARBON FILTER	ORGANIC TRAP	CATION EXCHANGER	ANION EXCHANGER
FTU	FTU	mg/1	mg/1	mg/1	FTU	mg/1	mg/1	FTU	FTU	FTU	FTU	FTU	FTU
88	8	10	0.10	35	2.5	250		5.4	3.9	3.6	3.4	0.46	0.40
56	14	10	0.10	15	6.0	250		8.8	7.0	7.6	8.2	1.5	2.2
65	14	10	0.10	15	6.0	250		8.1	6.2	5.8	5.6	1.3	3.0
66	15	10	0.10		6.3	250		4.7	4.6	3.6	6.6	2.3	0.46
23	21	10			5.4	250		12.0	12.0	11.0	12.0	1.4	1.2
60	17	10			5.9	250		6.1	7.0	5.1	7.0	1.4	1.1
55	18	10			7.7	-		5.3	5.1	4.8	5.4	4.6	3.4
64	16	10	0.05		5.4	100	1	9.4	9.4	10.0	12.0	3.4	2.4
58	22	10	0.05		5.8	100	2	8.8	8.4	8.8	9.7	6.7	5.6
88	22	10	0.05	25	3.4	100	5						
63	19	10	0.05	25	2.6	100	12						
59	30	10	0.10	25	4.5	170	12	8.0	6.6	6.4	6.4	1.6	1.3
58	18	10	0.05	25	4.2	200	12	5.4					
55	19	10	0.10	25	4.0	250	12	5.4					

(Continued)

TABLE 33. (CONTINUED)

PRESENT WASTEWATER TREATMENT PROCESS						WATER REUSE PROJECT							
UNTREATED MANUFACTURING WASTE	BIOLOGICALLY TREATED WASTE	CHEMICAL FEED RATES AHEAD OF MULTIMEDIA FILTERS			FINAL EFFLUENT	MPP CHEMICAL FEED RATES		EFFLUENT FROM					
		ALUM	POLYMER	P A C		ALUM	POLYMER	MOBILE PILOT PLANT	SAND FILTER	CARBON FILTER	ORGANIC TRAP	CATION EXCHANGER	ANION EXCHANGER
FTU	FTU	mg/1	mg/1	mg/1	FTU	mg/1	mg/1	FTU	FTU	FTU	FTU	FTU	FTU
51	21	10	0.10	25	4.5	250	12	5.0	4.4	4.2	4.4	1.3	0.98
60	33	10	0.10	10	4.6	250	12	7.1	6.1	5.8	6.1	1.4	1.1
100	32	10	0.10	10	4.2	250	12	3.0	3.5	3.2	2.9	0.92	0.9
69	25	10	0.10	10	7.0	150	3	7.7	7.4	7.8	7.3	1.6	0.88
15	22	10	0.10	10	4.0	200	3	5.5	6.4	5.5	5.2	0.64	0.4
44	15	10	0.10	10	2.3	200	3	6.2	5.3	6.7	6.5	1.1	1.2
55	7	10	0.10	10	2.2	250	3	5.0	4.5	4.4	4.5	0.9	0.75
44	21	10	0.10	10	5.0	250	3	5.5	5.3	4.9	4.8	1.1	0.85
24	31	10	0.10	10	9.0	350	3	20.0	18.0	18.0	18.0	2.6	1.3
52	30	10	0.10	10	11.0	350	3	2.5	1.7	1.6	1.2	0.6	0.49
47	20	10	0.10	10	17.0	350	3	4.3	3.1	3.1	1.2	0.6	0.49
30	17	10	0.10	10	5.5	350	3	6.7	2.1	0.94	1.1	0.61	0.56

TABLE 34. SPECIFIC CONDUCTIVITY

PRESENT WASTEWATER TREATMENT PROCESS				WATER REUSE PROJECT							
CHEMICAL FEED RATES AHEAD OF MULTIMEDIA FILTERS				MPP CHEMICAL FEED RATES		EFFLUENT FROM					
ALUM	POLYMER	P A C	FINAL EFFLUENT	ALUM	POLYMER	MOBILE PILOT PLANT	SAND FILTER	CARBON FILTER	ORGANIC TRAP	CATION EXCHANGER	ANION EXCHANGER
mg/1	mg/1	mg/1	umhos	mg/1	mg/1	umhos	umhos	umhos	umhos	umhos	umhos
10	0.10	35	610	250		640	630	640	690	2300	19
10	0.10	35		250		635	630	630	630	1600	16
10	0.10	35		250		610	615	615	615	1600	16
10	0.10	35	510	250		605	605	630	640	1400	84
10	0.10	35		250		490	490	500	515	1400	14
10	0.10	35		250		480	475	480	480	510	220
10	0.10	35	540	250		680	685	685	680	1800	44
15	0.5	35		250		800				3000	12
15	0.5	35	560	250		760	770	780	820	2700	10
10	0.25	35		250		780	790	780	800	2200	15
10	0.25	35	480	250		780	760	760	780	2200	36
10	0.25	35		250		700	700	700	710	2100	27
10	0.25	35		250		700	710	710	720	2100	30
10	0.25	35	460	250		680	680	690	700	2000	100

(Continued)

TABLE 34. (CONTINUED)

PRESENT WASTEWATER TREATMENT PROCESS				WATER REUSE PROJECT							
CHEMICAL FEED RATES AHEAD OF MULTIMEDIA FILTERS				MPP CHEMICAL FEED RATES		EFFLUENT FROM					
ALUM	POLYMER	P A C	FINAL EFFLUENT	ALUM	POLYMER	MOBILE PILOT PLANT	SAND FILTER	CARBON FILTER	ORGANIC TRAP	CATION EXCHANGER	ANION EXCHANGER
mg/l	mg/l	mg/l	umhos	mg/l	mg/l	umhos	umhos	umhos	umhos	umhos	umhos
10	0.10	35		250		710	710	710	700	1800	33
10	0.10	15		250		690	690	670	670	1700	30
10	0.10	15	590	250		710	710	710	720	1900	25
10	0.10		540	250		650	660	680	770	4500	32
10	0.10	10	590	250		630	670	670	720	2300	43
10	0.10	10	430	250		620	630	620	640	1900	42
10						540	550	510	550	1500	52
10	0.05		630	100	1	700	690	700	740	2200	14
10	0.05			100	2	610	610	610	630	1500	14
10	0.05	25		100	5	580					
10	0.05	25	550	100	12	540					
10	0.10	25		170	12	750	760	730	700	1450	20
10	0.05	25		200	12	520					
10	0.10	25		250	12	590					
10	0.10	25	520	250	12	750	740	740	730	1600	50

(Continued)

TABLE 34. (CONTINUED)

PRESENT WASTEWATER TREATMENT PROCESS				WATER REUSE PROJECT							
CHEMICAL FEED RATES AHEAD OF MULTIMEDIA FILTERS				MPP CHEMICAL FEED RATES		EFFLUENT FROM					
ALUM	POLYMER	P A C	FINAL EFFLUENT	ALUM	POLYMER	MOBILE PILOT PLANT	SAND FILTER	CARBON FILTER	ORGANIC TRAP	CATION EXCHANGER	ANION EXCHANGER
mg/1	mg/1	mg/1	umhos	mg/1	mg/1	umhos	umhos	umhos	umhos	umhos	umhos
10	0.10	10		250	12	750	750	745	750	1800	20
10	0.10	10	580	250	12	780	790	810	810	2200	18
10	0.10	10	440	150	3	590	600	600	620	1700	45
10	0.10	10		200	3	630	640	640	660	1850	40
10	0.10	10		200	3	620	630	650	650	1500	51
10	0.10	10	550	250	3	650	660	660	680	1600	47
10	0.10	10	350	250	3	650	640	640	660	1400	40
10	0.10	10		350	3	650	650	650	630	1300	37
10	0.10	10	400	350	3	640	640	640	700	2600	31
10	010	10		350	3	630	650	650	670	2100	26
10	0.10	10	420	350	3	650	650	650	650	1800	35

lower total solids concentration. Only a very minor reduction in total solids was realized through the combined treating of sand, carbon and organic scavenging filters; however, by the time treated wastewaters exited the anion exchanger, the last step in the pilot process, 85% of the total solids had been removed. Table 35 presents the total solids at various locations within the Total treatment system. When 350 mg/l alum was used in the MPP, the total solids levels in the pilot plant effluent were less than 50 mg/l, which indicated that a very high quality water had been generated.

Biochemical Oxygen Demand (BOD_5)

BOD_5 determinations were made using the standard 5-day incubation time and the procedure found in the fourteenth edition of Standard Methods For The Examination of Water & Wastewater. Dissolved oxygen was determined by a properly standardized dissolved oxygen meter. All samples were seeded with 5% secondary clarifier effluent (non-chlorinated). Table 36 is provided to show 5-day values for all major locations in the full-scale and pilot treatment processes. BOD_5 values were too low to be particularly meaningful; therefore, BOD_5, COD and TOC values have been compared in Table 39. BOD_5 in the influent to the pilot plant averaged 5.1 mg/l and was reduced almost sixty percent by the MPP unit alone; only about ten percent more reduction was realized through the 5-column train.

Chemical Oxygen Demand (COD)

Chemical oxygen demand was determined by the dichromate reflux method found in the fourteenth edition of Standard Methods For The Examination of Water & Wastewater. Less than half the total COD removal occurred in the MPP unit, with most occurring during treatment through the 5-column train. In Table 37 COD values throughout the whole wastewater treatment process have been shown.

Total Organic Carbon (TOC)

A Beckman Model 215 Carbon Analyzer was used for all TOC determinations. Acidified samples were Nitrogen sparged to remove carbonates and bicarbonates. Twenty microliter samples were used for analysis. Organic carbon was converted to carbon dioxide by reaction with pure oxygen at 950°C.; the newly converted carbon dioxide was measured and recorded. Total organic carbon was

TABLE 35. TOTAL SOLIDS (mg/l)

PRESENT WASTEWATER TREATMENT PROCESS						WATER REUSE PROJECT				
		CHEMICAL FEED RATES AHEAD OF MULTIMEDIA FILTERS				MPP CHEMICAL FEED RATES		EFFLUENT		
UNTREATED MANUFACTURING WASTE	2° BIOLOGICALLY TREATED WASTE	ALUM	POLYMER	P A C	FINAL EFFLUENT	ALUM	POLYMER	MOBILE PILOT PLANT	ORGANIC TRAP	ANION EXCHANGER
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
		10	0.10	35		250		500	390	34
	590	10	0.10	35	500	250		488		33
		10	0.10	35		250				
725	565	10	0.10	35	520	250		459		125
		10	0.10	35		250		428	346	26
780		10	0.10	35		250		545	420	230
		10	0.10	35		250		578	458	88
	510	10	0.50	35	495	250				
340		10	0.50	35		250				
	610	10	0.25	35	550	250				
745	535	10	0.25	35	490	250		474	362	75
	495	10	0.25	35	465	250		480	384	37
850		10	0.25	35		250		453	376	38
425		10	0.25	35		250		451	363	82
680		10	0.10	35		250		453	392	44

(Continued)

TABLE 35. (CONTINUED)

PRESENT WASTEWATER TREATMENT PROCESS						WATER REUSE PROJECT				
		CHEMICAL FEED RATES AHEAD OF MULTIMEDIA FILTERS				MPP CHEMICAL FEED RATES		EFFLUENT		
UNTREATED MANUFACTURING WASTE	2° BIOLOGICALLY TREATED WASTE	ALUM	POLYMER	P A C	FINAL EFFLUENT	ALUM	POLYMER	MOBILE PILOT PLANT	ORGANIC TRAP	ANION EXCHANGER
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
	550	10	0.10	15	520	250		478	416	50
600		10	0.10	15		250		480	410	47
	485	10	0.10		500	250		469	448	76
670		10				250		496	411	68
625		10				250				
	475	10			475	0		419	330	45
710		10	0.05			100	1	542	451	80
		10	0.05			100	2	499	453	90
	545	10	0.05	25	470	100	5			
		10	0.05	25	0	100	12			
		10	0.10	25		170	12	516	387	39
	540	10	0.05	25	470	200	12			
685		10	0.10	25		250	12			
545	595	10	0.10	25	500	250	12	482	392	50
680		10	0.10	10		250	12	503	378	48

(Continued)

TABLE 35. (CONTINUED)

PRESENT WASTEWATER TREATMENT PROCESS						WATER REUSE PROJECT				
		CHEMICAL FEED RATES AHEAD OF MULTIMEDIA FILTERS				MPP CHEMICAL FEED RATES		EFFLUENT		
UNTREATED MANUFACTURING WASTE	2° BIOLOGICALLY TREATED WASTE	ALUM	POLYMER	P A C	FINAL EFFLUENT	ALUM	POLYMER	MOBILE PILOT PLANT	ORGANIC TRAP	ANION EXCHANGER
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
	605	10	0.10	10	500	250	12	478	419	69
860		10	0.10	10	460	150	3	510	420	80
		10	0.10	10	490	200	3	430		77
	520	10	0.10	10	480	200	3			
		10	0.10	10		250	3			
	465	10	0.10	10	415	250	3	485	382	44
	520	10	0.10	10	485	350	3			
		10	0.10	10		350	3	537	429	12
	540	10	0.10	10	495	350	3	363	271	3
	535	10	0.10	10	425	350	3			

TABLE 36. BOD_5 (mg/l)

PRESENT WASTEWATER TREATMENT PROCESS						WATER REUSE PROJECT			
		CHEMICAL FEED RATES AHEAD OF MULTIMEDIA FILTERS				MPP CHEMICAL FEED RATES		EFFLUENT	
UNTREATED MANUFACTURING WASTE	BIOLOGICAL SYSTEM EFFLUENT	ALUM	POLYMER	P A C	FINAL EFFLUENT	ALUM	POLYMER	MOBILE PILOT PLANT	ANION EXCHANGER
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
375		10	0.10	35	4.9	250		2.4	1.7
385	11.0	10	0.10	35	3.8	250		1.8	1.5
315	13.7	10	0.10	35	3.9	250		1.7	1.3
260	13.5	10	0.10	35	5.6	250		1.8	1.4
350	12.3	10	0.10	35	5.3	250		2.6	2.0
355	12.0	10	0.10	35	5.4	250			
312	14.2	10	0.10	35	5.1	250			
415	5.8	15	0.50	35	7.5	250		1.9	1.0
290	23.7	15	0.50	35	13.5	250		2.4	1.4
325	29.7	10	0.25	35	12.5	250		4.7	4.5
330	19.0	10	0.25	35	8.0	250		1.8	1.7
350	4.9	10	0.25	35	3.6	250		1.4	1.2
312	7.1	10	0.25	35	3.2	250		1.5	1.4
185	8.4	10	0.25	35	2.8	250		1.4	2.2
325	10.0	10	0.10	35	3.5	250			
330	7.6	10	0.10	15	5.2	250		1.8	2.1
300	8.6	10	0.10	15	4.9	250		1.5	2.1
335		10	0.10		8.7	250		1.9	2.2
75		10			4.8	260			3.0
145	10.0	10			4.2	250		2.1	3.7
222	9.2	10			4.4	0	0	2.7	2.9
198	11.0	10	0.05		5.7	100	1	2.5	2.4
265	18.0	10	0.05		5.5	100	2	5.2	2.8

(Continued)

TABLE 36. (CONTINUED)

PRESENT WASTEWATER TREATMENT PROCESS						WATER REUSE PROJECT			
		CHEMICAL FEED RATES AHEAD OF MULTIMEDIA FILTERS				MPP CHEMICAL FEED RATES		EFFLUENT	
UNTREATED MANUFACTURING WASTE	BIOLOGICAL SYSTEM EFFLUENT	ALUM	POLYMER	P A C	FINAL EFFLUENT	ALUM	POLYMER	MOBILE PILOT PLANT	ANION EXCHANGER
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
390		10	0.05	25	2.7	100	5	2.4	
260		10	0.05	25	2.1	100	12	1.8	
273	9.3	10	0.10	25	4.5	170	12	1.9	2.5
263	10.3	10	0.05	25	5.1	200	12	2.4	
278	11.8	10	0.10	25	5.1	250	12	3.4	
193	15.3	10	0.10	25	5.3	250	12	1.9	1.7
230	10.7	10	0.10	10	4.1	250	12	1.6	1.4
220	12.3	10	0.10	10	3.7	250	12	1.1	2.9
325		10	0.10	10		150	3	2.6	2.3
205	6.0	10	0.10	10		200	3	1.3	1.1
235	5.8	10	0.10	10	3.1	200	3	2.8	1.5
215	8.5	10	0.10	10	2.8	250	3	2.5	1.3
295	7.0	10	0.10	10	3.1	250	3	1.0	1.4
175	8.3	10	0.10	10	5.1	350	3	3.7	1.5
288	4.3	10	0.10	10	4.3	350	3	1.2	1.1
255	7.0	10	0.10	10	6.4	350	3	1.2	1.0
273	7.0	10	0.10	10	4.5	350	3	0.9	1.2

TABLE 37. COD (mg/l)

PRESENT WASTEWATER TREATMENT PROCESS						WATER REUSE PROJECT			
		CHEMICAL FEED RATES AHEAD OF MULTIMEDIA FILTERS				MPP CHEMICAL FEED RATES		EFFLUENT	
UNTREATED MANUFACTURING WASTE	BIOLOGICAL SYSTEM EFFLUENT	ALUM	POLYMER	P A C	FINAL EFFLUENT	ALUM	POLYMER	MOBILE PILOT PLANT	ANION EXCHANGER
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
500		10	0.10	35		250		110.2	1.97
		10	0.10	35	194	250		96.0	3.92
		10	0.10	35		250			
		10	0.10	35		250			
		10	0.10	35		250			
		10	0.10	35		250			
		10	0.10	35		250			
		15	0.5	35		250		125.	<3.7
		15	0.5	35		250			
		10	0.25	35		250			
	321	10	0.25	35	231	250			
		10	0.25	35		250			
	288	10	0.25	35	229	250			
		10	0.25	35		250		123.	<2.0
1098		10	0.10	35		250		111.	18.5
		10	0.10	15		250			
	278	10	0.10	15	206	250		127.	19.8
		10	0.10		182	250		89.1	7.4
		10			189	250			28.1
960		10				250			
	242	10			177	0		84.5	7.7
	232	10	0.05		154	100	1	116.	3.7
		10	0.05	25		100	2		

(Continued)

TABLE 37. (CONTINUED)

PRESENT WASTEWATER TREATMENT PROCESS						WATER REUSE PROJECT			
		CHEMICAL FEED RATES AHEAD OF MULTIMEDIA FILTERS				MPP CHEMICAL FEED RATES		EFFLUENT	
UNTREATED MANUFACTURING WASTE	BIOLOGICAL SYSTEM EFFLUENT	ALUM	POLYMER	P A C	FINAL EFFLUENT	ALUM	POLYMER	MOBILE PILOT PLANT	ANION EXCHANGER
mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
		10	0.05	25		100	5	154.	34.4
960	249	10	0.10	25	170	100	12		
995		10	0.05	25		170	12	130.	34.4
		10	0.10	25		200	12		
		10	0.10	25		250	12		
		10	0.10	25		250	12	104.	11.6
		10	0.10	10		250	12		
		10	0.10	10		250	12		
		10	0.10	10	155	150	3	128.	32.0
		10	0.10	10		200	3	98.4	7.9
		10	0.10	10	152	200	3	118.	19.0
845		10	0.10	10		250	3	103.	4.0
		10	0.10	10		250	3		
		10	0.10	10		350	3	173.	7.5
887		10	0.10	10		350	3	81.3	7.4
		10	0.10	10		350	3	76.9	<4.0
		10	0.10	10		350	3	84.0	<4.0

TABLE 38. TOTAL ORGANIC CARBON

PRESENT WASTEWATER TREATMENT PROCESS				WATER REUSE PROJECT			
CHEMICAL FEED RATES AHEAD OF MULTIMEDIA FILTERS			FINAL EFFLUENT mg/l	MPP CHEMICAL FEED RATES		EFFLUENT	
ALUM mg/l	POLYMER mg/l	PAC mg/l		ALUM mg/l	POLYMER mg/l	MOBILE PILOT PLANT	ANION EXCHANGER mg/l
TOTAL ORGANIC CARBON							
15	0.50	35	100	250	-	56	50
10	0.25	35	67	250	-	-	4
10	0.10	35	60	250	-	59	4
10	0.10	15	66	250	-	42	10
10	0.10	-	61	250	-	36	6
10	-	-	64	250	-	30	5
10	0.10	25	140	250	3	74	10
10	0.10	10	62	150	3	60	12
10	0.10	10	56	250	3	36	4
10	0.10	10	62	250	3	31	<1
10	0.10	10	28	350	3	26	2
10	0.10	10	74	350	3	28	2

calculated by proportioning peak level of sample to peak level of a known standard. Only about fifteen percent TOC was removed by the MPP unit while seventy-five percent of the remaining TOC was removed by the 5-column train. See Table 38 for comparison.

The BOD_5, COD and TOC values and removal efficiencies have been compared in Table 39 for the pilot treatment plant.

TABLE 39. POLLUTANT REMOVALS VIA PILOT PLANT

	MPP Unit			5-Column Train		Total Pollutant Removed	
Parameter	Influent	Effluent	% Removed	Effluent	% Removed	mg/l	%
BOD_5	5.14	2.13	59	1.92	10	3.22	63
COD	185	105	43	11	90	174	94
TOC	61	51	16	13	75	48	79

While most BOD_5 removal was accomplished in the MPP unit, the 5-column train was needed to remove most of the COD and TOC present. The ratios of COD to BOD_5 and TOC to BOD_5 increase noticeably between initial influent and final effluent values.

The Nitrogen Group - Ammonia, Nitrates, Total Kjeldahl Nitrogen (TKN)

Considerable data was accumulated on the Nitrogen group made up of ammonia, nitrates, and TKN, because of concerns over these parameters in present and future permits to discharge wastewater to streams.

The nitrate analysis was performed according to procedures in the 1974 edition of EPA's manual of Methods for Chemical Analysis of Water & Wastes. The brucine method was used. An intense yellow color resulted from the reaction of nitrate and brucine after a reaction time of twenty-five minutes at 100°C. this yellow color was measured spectrophotometrically at 410 nm wavelength.

Both ammonia and TKN were determined according to procedures in the fourteenth edition of Standard Methods For The Examination of Water & Wastewater. Ammonia was determined by adjusting pH to 9.5, distilling it into boric acid, titrating with 0.02 N sulfuric acid and calculating the Nitrogen present as ammonia. The TKN was determined by converting the organic Nitrogen to a Mercury ammonium complex. This complex was decomposed by sodium thiosulfate and the ammonia distilled from an alkaline medium and absorbed in boric acid. Titration was by 0.02 N sulfuric acid and thus was calculated.

The determined ammonia, nitrate and TKN values have been recorded in Table 40. Ammonia levels were usually less than 0.3 mg/l when final effluent wastewater was received as influent to the pilot treatment plant. Therefore, it was not possible to evaluate the effectiveness of ammonia removal via the steps in this pilot plant. A small amount of nitrates were present in the pilot plant influent, at usually less than one mg/l concentration. Very little nitrate was used in the dyeing and finishing plants and this particular wastewater was considered nitrogen deficient, so that nitrate (as $NaNO_3$) was added prior to biological treatment to insure adequate nutrient levels for biological conversion. Some nitrate was removed through the MPP unit, with almost all the remaining removed through the 5-Column train.

Most of the Nitrogen in the pilot plant influent was in the form of organic Nitrogen or TKN. Because the ammonia was usually below the accurate detection limits the organic Nitrogen level was considered to be the TKN level. Addition of alum with and without polymeric coagulant aids, ahead of the MPP reactor/clarifier provided some TKN removal. This removal was approximately thirty percent on the average. The 5-Column unit further reduced TKN levels by an additional seventy-four percent to approximately 0.5 mg/l.

A major problem at this location, referred to earlier, was final effluent TKN concentration versus NPDES permit requirements for the final six months of the current permit period. This pilot study underscored a basic premise that the TKN remaining in the final effluent to the stream, as currently treated, would be extremely difficult to remove technically and that removal would be economically prohibitive. Further, the TKN remaining in the MPP unit effluent was sufficiently high that it would not

TABLE 40. NITROGEN SERIES

PRESENT WASTEWATER TREATMENT PROCESS				WATER REUSE PROJECT			
CHEMICAL FEED RATES AHEAD OF MULTIMEDIA FILTERS			FINAL EFFLUENT mg/l	MPP CHEMICAL FEED RATES		EFFLUENT	
ALUM mg/l	POLYMER mg/l	P A C mg/l		ALUM mg/l	POLYMER mg/l	MOBILE PILOT PLANT	ANION EXCHANGER mg/l
NITRATES							
15	0.50	35	0.2	250	-	0.2	<0.1
10	0.25	35	0.2	250	-	0.3	<0.1
10	0.10	35	0.2	250	-	0.4	<0.1
10	0.10	15	0.3	250	-	<0.1	<0.1
10	-	-	1.6	250	-	-	<0.3
10	0.10	10	<0.1	250	3	0.4	<0.1
10	0.10	10	0.4	350	3	0.2	<0.1
10	0.10	10	<0.1	350	3	0.2	<0.1
AMMONIA NITROGEN							
10	0.10	35	<0.3	250	-	<0.3	<0.3
15	0.50	35	<2.0	250	-	<2.0	<2.0
10	0.25	35	<0.3	250	-	<0.3	<0.3
10	0.10	35	<0.3	250	-	0.45	<0.3
10	0.10	15	<0.3	250	-	<0.3	<0.3
10	-	-	<0.3	250	-	<0.3	<0.3
10	0.10	10	<0.05	250	3	<0.3	<0.3
10	0.10	10	0.3	250	3	<0.3	<0.3
10	0.10	10	0.4	350	3	<0.3	<0.3
10	0.10	10	<0.3	350	3	<0.3	<0.3

(Continued)

TABLE 40. (CONTINUED)

PRESENT WASTEWATER TREATMENT PROCESS				WATER REUSE PROJECT			
CHEMICAL FEED RATES AHEAD OF MULTIMEDIA FILTERS				MPP CHEMICAL FEED RATES		EFFLUENT	
ALUM mg/l	POLYMER mg/l	P A C mg/l	FINAL EFFLUENT mg/l	ALUM mg/l	POLYMER mg/l	MOBILE PILOT PLANT	ANION EXCHANGER mg/l
TOTAL KJELDAHL NITROGEN							
15	0.50	35	<2.0	250	-	<2.0	<2.0
10	0.25	35	2.2	250	-	1.2	0.3
10	0.10	35	1.7	250	-	2.0	<0.3
10	0.10	15	2.8	250	-	1.7	0.3
10	-	-	2.4	250	-	4.2	0.3
10	0.10	25	4.2	250	-	2.3	<0.3
10	0.10	10	3.6	150	3	2.1	0.4
10	0.10	10	2.2	250	3	2.2	0.4
10	0.10	10	2.6	250	3	2.1	0.8
10	0.10	10	3.1	350	3	1.4	0.3
10	0.10	10	5.0	350	3	1.2	0.5

be possible to meet NPDES requirements of eighty-three pounds per day final effluent TKN level, should total flow be increased significantly. The volume of sludge which would be generated with a coagulation process would be completely disproportionate to the small amount of TKN which would also be removed, i.e. the cost for the incremental removal would not be justified.

Total Phosphorus

Total Phosphorus was determined by the Ascorbic Acid method following Persulfate digestion as prescribed in the procedures found in the 1974 edition of EPA's manual of Methods for Chemical Analysis of Water & Wastes. This parameter was monitored because of tremendous interest in phosphorus levels in North Carolina streams as a result of phosphate mining and fertilizer plants within the state. Total Phosphorus levels generally present no problem; however, on some days levels are unusually high (8 mg/l or more). The MPP unit removed significant amounts of Phosphorus; indications were that the greater the alum dosage, the lower the effluent concentration as shown in Table 41. Approximately two-thirds of the total Phosphorus was removed via the MPP unit and almost all of the remaining one-third was removed via the 5-Column train.

Chlorides

Chlorides were determined according to the mercuric nitrate method given in the fourteenth edition of Standard Methods For the Examination of Water & Wastewater.

Influent to the pilot plant contained low chloride levels (20-70 mg/l). As shown in Table 41, no consistent or significant change occurred in the MPP unit. However, the 5-Column train, largely the anion exchanger, removed chlorides to below 10 mg/l concentration. Such a low level would offer no problems to water reuse in dyeing and finishing.

Sulfates

The sulfate analysis was according to the turbidimetric method given in the fourteenth edition of Standard Methods For the Examination of Water & Wastewater.

TABLE 41. PHOSPHORUS, CHLORIDES, SULFATE

PRESENT WASTEWATER TREATMENT PROCESS				WATER REUSE PROJECT			
CHEMICAL FEED RATES AHEAD OF MULTIMEDIA FILTERS				MPP CHEMICAL FEED RATES		EFFLUENT	
ALUM mg/l	POLYMER mg/l	P A C mg/l	FINAL EFFLUENT mg/l	ALUM mg/l	POLYMER mg/l	MOBILE PILOT PLANT	ANION EXCHANGER mg/l
TOTAL PHOSPHORUS							
15	0.50	35	4.9	250	-	1.1	0.10
10	0.25	35	7.9	250	-	1.0	<0.10
10	0.10	35	6.2	250	-	5.7	0.06
10	0.10	15	7.4	250	-	1.4	0.30
10	-	-	8.6	250	-	1.1	0.11
10	0.10	25	8.7	250	-	1.3	<0.10
10	0.10	10	12.1	150	3	5.2	<0.10
10	0.10	10	7.7	250	3	3.3	0.10
10	0.10	10	7.0	250	3	1.3	<0.10
10	0.10	10	9.9	350	3	3.9	<0.10
10	0.10	10	5.8	350	3	0.4	<0.10
CHLORIDES							
15	0.50	35	69	250	-	73	2
10	0.25	35	19	250	-	49	2.5
10	0.10	35	50	250	-	49	4.0
10	0.10	15	25	250	-	1.9	3.2
SULFATES							
15	0.50	35	2	250	-	84	<5
10	0.25	35	<5	250	-	73	1
10	0.10	35	23	250	-	36	<5
10	0.10	15	<5	250	-	66	<5
10	0.10	10	33	350	3	160	<5

Sulfate levels in process treated wastewater varied greatly from approximately two to thirty mg/l which resulted from variations in sulfate containing chemicals useage in dyeing and finishing. Sulfate concentration was inconsequential in this wastewater, which became the influent to the pilot plant, because the sulfate level was significantly increased in the MPP unit by the alum (aluminum sulfate) additions. As shown in Table 41, the 5-column train effectively removed the sulfates to below five mg/l. The higher the alum dosage needed in the MPP unit for removal of any one of several specific parameters, the greater the sulfate level which would be removed in the anion exchanger. The efficiency of the anion exchanger would be greatly reduced if high alum dosages became necessary in a full-scale plant modeled after this pilot treatment plant.

Metals

Metals were analyzed by atomic absorption procedures. Table 42 provides information on metals analyses for multimedia filter effluent. MPP effluent and anion exchanger effluent for the metals Aluminum, Antimony, Calcium, Copper, Chromium, Iron, Magnesium, Manganese and Zinc.

Only trace amounts of Chromium and Manganese were found in the multimedia filter effluent, so no meaningful evaluation of their removal could be made. It was considered likely that the pilot plant would effect removals of virtually any amounts of these found in dyeing and finishing wastewaters.

Aluminum concentration was noticeably increased by alum dosages in the MPP unit; however, the final effluent from the pilot plant showed less than 0.5 mg/l.

Increases in concentrations of Iron and Zinc following treatment through the MPP unit were determined to be from tramp metals in the alum source used. The 5-column train effectively removed these multivalent metals from wastewater. This was important because of known metal-dye complexes which cause dye shade changes on fabrics; such would likely preclude reuse of any waters containing significant amounts (greater than 0.5 mg/l) of Chromium, Copper, Iron, Manganese, Magnesium and Zinc.

The presence of significant amounts of these metals in any wastewater being considered for reuse would have to be taken into account when evaluating

TABLE 42. METAL SERIES

ALUM mg/l	P A C mg/l	POLYMER mg/l	ALUMINUM ug/l	ANTIMONY ug/l	CALCIUM mg/l	CHROMIUM ug/l	COPPER ug/l	IRON ug/l	MAGNESIUM mg/l	MANGANESE ug/l	ZINC ug/l
METAL ANALYSES ON MULTIMEDIA FILTER EFFLUENT											
10	35	0.10	-	-	-	< 30	40	-	-	-	70
10	35	0.50	600	570	8.7	< 30	40	420	1.4	< 30	110
10	35	0.25	500	690	8.7	< 30	60	480	1.6	< 30	110
10	35	0.10	1100	880	7.9	< 30	80	270	1.2	< 30	110
10	15	0.10	500	1300	-	50	90	390	-	-	110
10	-	0.10	-	-	-	< 30	50	-	-	-	160
10	10	0.10	-	-	-	< 30	90	-	-	-	290
10	-	0.05	900	950	-	30	60	360	-	-	80
10	25	0.05	2100	990	-	< 30	90	330	-	-	60
10	25	0.10	-	-	-	< 30	120	-	-	-	90
10	10	0.10	-	-	-	60	100	-	-	-	90
10	10	0.10	1300	1500	-	< 30	110	190	-	-	110
10	10	0.10	-	-	-	< 30	90	-	-	-	60
METAL ANALYSES ON MPP EFFLUENT											
250	-	-	2900	1600	9.7	< 30	70	850	1.5	< 30	350
250	-	-	1900	510	8.5	< 30	90	990	1.3	40	290
250	-	-	1400	710	8.5	< 30	80	970	1.5	< 30	190
250	-	-	900	900	7.7	< 30	90	560	1.4	< 30	185
250	-	-	2400	1400	8.2	< 30	110	580	1.6	70	340
100	12	-	1200	-	-	-	-	-	-	-	-
170	12	-	1800	-	-	-	-	-	-	-	-
150	3	-	2900	860	-	50	180	-	-	-	-
200	3	-	2400	1100	-	< 30	150	-	-	-	-
350	3	-	8800	-	-	-	-	-	-	-	-
350	3	-	700	-	-	-	-	-	-	-	-
350	3	-	1400	-	-	-	-	-	-	-	-

(Continued)

TABLE 42. (CONTINUED)

ALUM mg/l	P A C mg/l	POLYMER mg/l	ALUMINUM ug/l	ANTIMONY ug/l	CALCIUM mg/l	CHROMIUM ug/l	COPPER ug/l	IRON ug/l	MAGNESIUM mg/l	MANGANESE ug/l	ZINC ug/l
METAL ANALYSES ON ANION EXCHANGER EFFLUENT											
			800	1200	0.02	< 30	<20	< 30	.090	< 30	< 30
			100	< 500	0.08	< 30	<20	50	.015	< 30	< 30
			100	< 500	0.14	< 30	<20	210	.016	< 30	< 30
			200	< 500	0.16	< 30	<20	< 30	.012	< 30	< 30
			1400	< 500	0.14	< 30	<20	470	.016	< 30	< 30

various treatment methods to render waters suitable for critical manufacturing operations.

OPERATIONAL PROBLEMS OF THE PILOT PLANT

A number of problems were encountered with the pilot plant and its operation during the approximately eleven months of operation. The MPP unit was operated from December 1975 through November 1976 while the 5-column train was operated from late February 1976 through November 1976.

The initial problem was one of frozen pipes in the MPP unit during the severe late December to early February cold. This problem was solved by keeping water flowing through on a continuous basis. Operation as a reactor/clarifier was carried out only during the warmer part of the day and on several extremely cold days the unit could not be operated. The 5-column train was protected somewhat by shelter and was operated without damage from freezing.

Variable chemical feed pumps in the MPP unit gave tremendous reliability problems. The solution was finally to calibrate them for a fixed feed rate and vary the chemical feed concentration in the stock solution to give the desired chemical dosages.

Two operational problems were encountered with the MPP unit. A foaming problem occurred in the rapid mix tank when 100 mg/l or more alum was used. This foaming problem was likely aggravated by residual surface active materials in the wastewater. The solution to this problem was to stop the rapid mixer and depend on the slow mixer in the first flocculator tank for providing the level of contact needed between alum and the suspended waste particles. The second, more important problem was the very short runs when alum dosages were 250 - 350 mg/l. Very large quantities of settleable alum floc was generated which quickly overloaded the settling tubes in the tube clarifier and backwashing was then required after only two hours operation. This problem would be overcome in a full-scale coagulator by provisions for intermittent and/or continuous sludge wasting.

The 5-column train was operated with fewer mechanical equipment problems. The major problem was adjusting the regenerant feed rates during backwashing/regeneration by use of an aspirator and valve system which was very difficult to adjust. This problem would not be encountered in a full scale model of this pilot plant because the aspirators would be replaced by metering pumps.

Two other operational problems were encountered with the 5-column train. Resin losses from organic scavenging, cation exchanger, and anion exchanger columns during backwash regeneration was a problem which was tied to the above mentioned problem of controlling flow during this step. The second problem was the need for an operator to be in attendance at all times during the complete regeneration cycle - a cycle which took some seven and one-half hours when all five columns had to be regenerated. This regeneration time often had to be spread over two days which greatly reduced effective equipment run time.

Backwash/regeneration time and gallons through-put for each of the pilot plant component parts has been shown below for normal operation. These time requirements were often much longer when equipment problems occurred.

Pilot Plant Component	Normal Gallons Through-Put or Before Backwash (BW) and/or Regeneration (Reg)	Backwash and/or Regeneration Time Required
MPP Trailer	4200 BW	1/2 Hour
Sand Filter	1/wk BW	1/2 Hour
Carbon Filter	1/wk BW	1/2 Hour
Organic Trap	as anionic column (BW + Reg.)	2 Hours
Cation Exchanger	1200 BW + Reg.	2 Hours
Anion Exchanger	1900 BW + Reg.	2-1/2 Hours

The other limiting factor to pilot plant operation was the quality of the influent wastewater. If the biological plant gave problems, these problems had to be corrected before any pilot plant runs could be made, due to manpower availability. No pilot runs were made when the influent had unusually high turbidity (70-100 JTU) which normally followed a biological plant upset. After a manufacturing plant shutdown of two days or longer, one or more days usually passed before initiating further pilot plant runs due to abnormally high amounts of fine suspended matter in the multimedia filter effluent.

The major effects of these problems was an extension of the time required to complete the project and a reduction of the number of experiments possible to run.

SECTION 8

LABORATORY REUSE EVALUATIONS

Laboratory investigations were conducted to determine if residual color in the multimedia filter effluent would be scavenged by fibers during conventional dyeing operations. If the residual color were not scavenged, it would be theoretically possible to find a dyeing procedure to reuse a portion of the wastewater without considerable further treatment. This would make treatment for dyeing and finishing reuse more attractive economically.

LABORATORY DYE SCAVENGING EVALUATION

Laboratory experiments were carried out in the plant dye laboratory. Greige knitted fabric (tricot) was used for ease of handling. The various test fabrics were made from (a) type 6 caprolactam nylon, dull luster; (b) secondary cellulose acetate, dull luster; (c) knitted fabric blend of 80% cellulose triacetate, dull luster, and 20% type 6 caprolactam nylon, dull luster; and (d) homopolymer polyester, dimethylterephthalate type, semi-dull luster. It should be stated that the 80% triacetate/20% nylon tricot construction was used for evaluating triacetate. The tricot knitted construction sufficiently hides the nylon so that the discoloration noted is contributed by the triacetate and not by the nylon. For the purposes of this experiment, this fabric was considered as representative of triacetate fiber.

In this investigation, dyeings using three different sources of water were made on each fabric as follows:

1. Laboratory water, ground water cation exchange treated for production use. Pt-Co color less than two units. (this was the control for the experimentation.)
2. Wastewater after full-scale multimedia filtration at the wastewater treatment plant (not the pilot installation). Pt-Co color - 400 units.

3. Wastewater blended with cation exchange treated water for processing fabric in the manufacturing plant's dyeing and finishing operation. A blend of 100 ml. wastewater with 900 ml. of laboratory water. Pt-Co Color - 40 Units.

The four fabrics were also scoured in the three sources of water identified above. No optical brightener was added. Scouring of 20-gram swatches of fabric were made in a steam-heated water bath in one-liter stainless steel beakers. A 50:1 liquor to goods (weight) ratio was a standard laboratory procedure.

Three 20-gram swatches of each of the four greige fabrics were prepared. Four stainless steel beakers were then filled with each of the three types of water to be used, making a total of twelve. Then each beaker was charged with the following chemicals: (a) one gram per liter of a proprietary solvent scour (60% aromatic and aliphatic solvent blend/40% anionic and nonionic surfactant blend), (b) one gram per liter of sodium tripolyphosphate. The fabric swatches were impaled on sharp stainless steel rods coiled over beaker positions on the steam-heated water bath where the scours were to be made. A motor driven attachment stirs the swatches by a reciprocating up/down motion in the beaker.

The water and chemical charged beakers were placed on the water bath and the swatches were lowered into the beakers via stainless steel rods, which were attached to the reciprocating stirring mechanism. Stirring was begun at once as the temperature was raised to 71^{o}C (160^{o}F) and maintained at that temperature for twenty minutes. After that length of time, an additional chemical charge of 0.2 grams per liter of citric acid was added to each beaker and the scouring was continued uninterrupted for an additional ten minutes. At the end of this thirty-minute total scouring cycle, the swatches were raised via the rods from the beakers. The change of pH during scouring was to allow color scavenging to take place under both alkaline and acid conditions. Alkaline and acid conditions are both common in production dyeing processes.

After this scouring cycle, each swatch was removed from the retainer coil and rinsed by hand under tap water (cation exchange treated) for thirty seconds. Swatches were then centrifugally extracted in a laboratory ten-pound model extractor to remove excessive water (approximately 20% moisture by weight of fiber remaining). Swatches were then drawn taut onto pin frames and dried in a forced draft laboratory oven for 75 seconds at 190°C (375°F). The three scoured swatches of each fabric were dried simultaneously to minimize any color variation from the drying step. After drying, swatches were removed from the pin frames and allowed to come to thermal equilibrium under ambient laboratory conditions. Swatches were examined visually after they had been brought to equilibrium. The observations are presented in Table 43 to show how those scoured in 100% treated wastewater and 10% treated wastewater/90% cation ion-exchange treated water compared to the control scoured in the cation ion-exchange treated laboratory water.

TABLE 43. VISUAL COMPARISON OF COLOR SCAVENGING BY VARIOUS FIBERS SCOURED IN WASTEWATER (Secondary Clarified, Chlorinated, Multimedia Filter[illegible])

Fiber	100 ml Treated Water/ 900 ml Cation ion Exchange Treated Water Pt-Co Units = 40	Position*	100% Treated Wastewater Pt-Co Units = 400	Position*
Type 6 Caprolactam Nylon	Very noticeable Discoloration	4	Very Severe Discoloration	4
Secondary Acetate	Very slight discoloration	2	Noticeable Discoloration	2
80/20% Triacetate/ nylon	Very noticeable Discoloration	3	Severe Discoloration	3
Polyester (disperse dyeable)	Very slight Discoloration	1	Slight Discoloration	1

*1 = least amount of staining; 4 = greatest amount of staining

This series of experiments shows that the various fibers scavenge color from tertiary treated wastewater in differing amounts. Type 6 nylon scavenged the most color, even more than triacetate; these two fibers scavenge several times more color than either secondary acetate or polyester. A dyeing and finishing plant processing nylon and/or triacetate could not use even the ten percent blend of tertiary-treated wastewater with ninety percent of its regular process water for scouring at temperatures up to 71°C (160°F) when treated wastewater color was 400 Pt-Co units or higher. A plant dyeing and finishing only acetate and/or polyester could consider this 10/90 blend where scouring would be carried out at a temperature of 71°C (160°F) or less. However, unless the plant was using extremely large amounts of water for scouring below 71°C (160°F) there would be no economic justification for considering such a blend of waters.

This series of experiments indicated that neither scouring nor dyeing with this 10/90 blend of water could be considered in a plant dyeing and finishing nylon and/or triacetate because of their severe residual color scavenging effect. These two fibers comprised about 50 percent of the fabrics which are dyed and finished at this location. In order to make the color scavenging effect of fibers in fabric form more objective, whiteness was determined for the two samples scoured in (a) 100% treated wastewater, and (b) 10% treated wastewater, compared to a control scoured in cation exchange treated water used for in-plant processing. Whiteness was determined on these scoured, untinted, non-optically brightened fibers in fabric form by use of American Association of Textile Chemists & Colorists Test Method 110-1975, "Reflectance, Blue and Whiteness of Bleached Fabric." The formula for whiteness found in paragraph 3.3 of this Test Method was used; it is: $W=4B-3G$ where W = Whiteness; B = Blue reflectance; and G = Green reflectance. See Table 44 for a presentation of the numerical values. The reflectance values for Blue and Green filter readings were used to calculate whiteness. The instrument used to determine reflectance using blue and green filters was a Gardner multi-purpose reflectometer.

TABLE 44. INSTRUMENT WHITENESS COMPARISON, CONTROL VERSUS WASTEWATER SCOURED FIBERS IN FABRIC FORM

FIBER	CONTROL	100 ML Treated Water/ 900 ML Cation Exchange Treated Water	100% Treated Wastewater
Type 6 Caprolactam Nylon	71	64	45
Secondary Acetate	68	66	60
80/20% Tri-Acetate/ Nylon	64	61	48
Polyester (Disperse Dyeable)	68	67	64

These whiteness readings confirmed the visual evaluation shown in Table 43. Even if residual color remaining in the tertiary-treated wastewater was only 40 Pt-Co units, this water would be unsuitable for processing nylon and triacetate. The processing of secondary acetate and of disperse dyeable homopolymer polyester should be considered only if further residual color reduction was accomplished by some means such as improved removal of color or even dilution to further reduce total residual color. The seriousness of even considering this approach must be underscored because (a) a dyeing and finishing plant would necessarily be handicapped by being able to process only certain fibers and (b) the scavenging effect of other fibers, natural, animal and man-made is unknown and would require further extensive investigation. This experiment further strengthened the need for a water reuse evaluation. It was well established that color removal from wastewater was difficult and was made even more difficult by small amounts of residual color contributed by several classes of both water-soluble and water-insoluble dye types.

RESULTS OF COMPARATIVE DYEINGS USING MOBILE PILOT PLANT (MPP) EFFLUENT

Relative whiteness was used as a measure of the effect of these efforts to obtain water sufficiently higher in quality and lower in color which could be satisfactorily reused in the dyeing and finishing of man-made fiber fabrics. Water taken from several pilot plant runs was used to dye whites on nylon and polyester; these two fibers were selected because nylon was demonstrated to be an effective scavenger of color bodies from this particular treated wastewater, and polyester was demonstrated as being the least affected by very large amounts of color in the dyebath water.

Table 45 shows the relative whiteness of nylon and polyester fabrics dyed using MPP effluent from selected pilot plant runs over the duration of the pilot wastewater reuse study. There were several apparent discrepancies when comparing relative whiteness of the swatches dyed using control process water versus recycled water from the pilot plant effluent. Samples E and F in Table 45 indicate essentially the same whiteness on the control dyeing and on recycled water dyeing. Note however, that the color of the pilot plant effluent used for dyeing these two samples was high. Compare nylon Samples E and F with sample H; when sample H was dyed using pilot plant effluent having 35 Pt-Co units of color, it showed a significant difference in relative whiteness compared to the control dyeing made at the same time. While samples E and F were not affected by high amounts of residual color in the pilot plant effluent used for dyeing (20 and 40 Pt-Co units respectively); sample H, when dyed in pilot plant effluent containing 35 Pt-Co units of color, showed a marked reduction in relative whiteness, 63 versus 69 for the control, which indicated the fiber scavenged color from the pilot plant effluent. The most logical explanation is that the color bodies in the pilot-treated wastewater for samples E and F had no affinity for the nylon fiber while those color bodies present at the time sample H was dyed did have affinity for the nylon fiber. This should be understood in view of the number and complexity of different dyes used in the manufacturing plants and the potential for chemical change which could cause the above apparent difference in residual color scavenging.

The nylon samples J and K showed definite color scavenging effects when dyed in pilot plant effluent containing only two to three Pt-Co units of color. The only explanation given was that certain acid dyes were not removed by the pilot treatment scheme and those were sufficiently neutral dyes to be exhausted onto nylon at pH 6. Dyeing results on nylon at less than two Pt-Co units

TABLE 45. RELATIVE WHITENESS OF DYED FIBERS (FABRIC FORM)

Sample	Fabric Fiber	Recycled Water Pt-Co Units Color	Water Recycle Date	Relative Whiteness	
				Control	Recycled Water
A	Nylon 6	125*	1/14/76	79	69
B	Nylon 6	25*	1/15/76	74	63
C	Polyester	125*	1/14/76	77	73
D	Polyester	25*	1/15/76	74	74
E	Nylon 6	20	4/7/76	68	69
F	Nylon 6	40	5/5/76	73	74
G	Nylon 6	8	5/26/76	67	65
H	Nylon 6	35	6/2/76	69	63
J	Nylon 6	2	3/8/76	76	71
K		3	3/10/76	76	72
L	Polyester	2	3/8/76	74	74
M		3	3/10/76	74	74
N	Nylon	<2	11/8/76	63	63
P	Polyester	<2	11/8/76	63	63

Whiteness determined by Reflectance using American Association of Textile Chemist & Colorist Test Method 110-1975.

*Wastewater Treatment Plant effluent recycled only through MPP Coagulation/Settling/Filtration Unit and not through 5-column train.

Control dyeings were all made from regular in-plant process water; water source was deep well; prior treatment was through cation exchange resin systems followed by decarbonizing.

of color, however, were equal in quality to the results of the control dyeing. When color was reduced below two Pt-Co units, water was satisfactory for dyeing all fibers in whites and very light pastel shades, as well as in a full range of normal shades.

Figure 6 shows the color comparison made spectrophotometrically for wastewater treated on November 8, 1976. Effluent from the full-scale wastewater treatment plant including biological treatment, chlorination and multimedia filtration with pre-filtration additions of 10 mg/l alum, 0.10 mg/l anionic polymer and 10 mg/l powdered activated carbon has been shown as "influent to MPP". This influent to the MPP had 200 Pt-Co units of color. This wastewater was treated in the MPP coagulation/settling/filtration unit with 350 mg/l alum, and 3 mg/l anionic polymer; effluent from this part of the pilot unit shown on the graph was also found to have 45 Pt-Co units of color or a reduction of 77.5% color. Further treatment through the 5-Column train gave a very clear, essentially colorless effluent, which has been shown on the top of the graph in Figure 6 and which was found to have less than two Pt-Co units of color. Shown in Figure 7 for comparative purposes, is a pilot plant run made on 9/16/76 and compared to laboratory tap water (plant process water). Note that the pilot plant effluent was essentially equally as color free as the tap water control.

The series of pilot plant runs made during November, 1976 using secondary clarified, chlorinated wastewater having 175-250 Pt-Co units of color as influent, gave a pilot plant effluent essentially color free; all four runs were measured as having a maximum of two Pt-Co units of color. However, extremely heavy chemical feeds ahead of the reactor/clarifier were used to achieve that color level, 350 mg/l alum and 3 mg/l anionic polymer. In addition, these four runs were through the entire 5-Column train including sand filtration, organic scavenging, granular activated carbon, cation and anion exchange resins. The required high concentration of chemical feeds created very high capital and operating costs as well as the need for sophisticated wastewater treatment in the scale-up to a one million gallon-per-day plant, presented in Section 9.

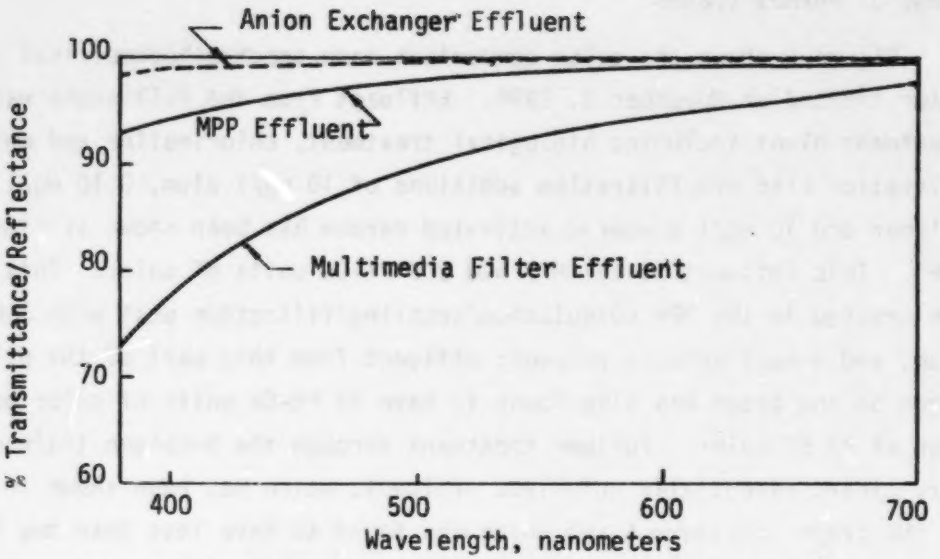


FIGURE 6. EFFLUENTS COLOR COMPARISON, 11/8/76

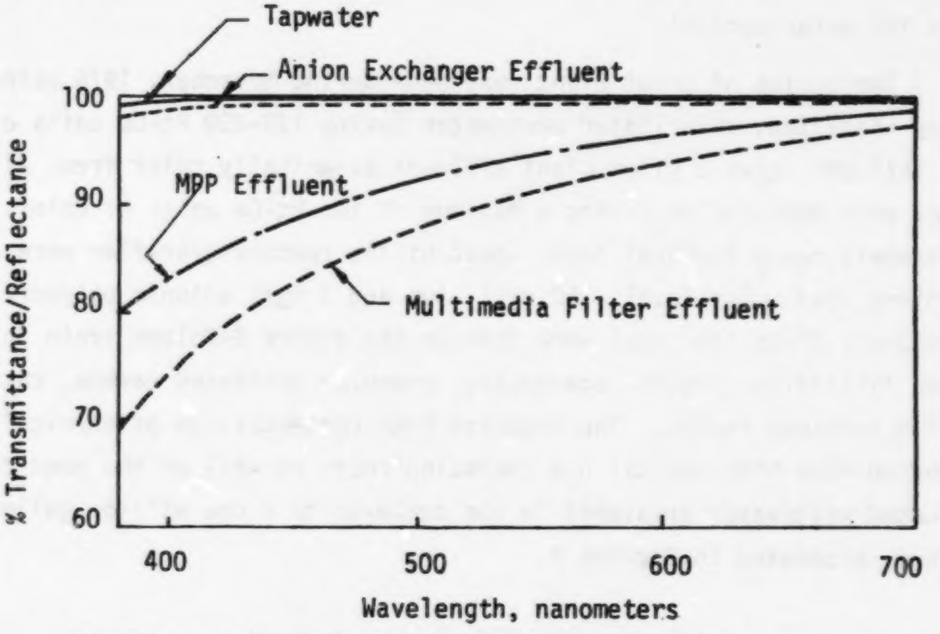


FIGURE 7. EFFLUENTS COLOR COMPARISON, 9/16/76

The results of dyeing polyester indicated the greater likelihood of success in treating wastewater treatment plant effluent to a reduced level of color and other parameters which would allow it to be successfully reused for scouring and possibly for dyeing in the manufacturing plant. However, several factors must be taken into consideration. The lower the process water temperature, the greater the likelihood of success with reuse of treated wastewater. Certain processes such as scouring at temperatures below the boil and scours at high pH's would be more easily adaptable. Extreme care would be required, however, when considering high temperature (110-130°C or 230-265°F) dyeing of polyester with this type of advanced treated wastewater. Some dyes, particularly Anthraquinone Red dispersed dyes, are extremely sensitive to certain metal ions such as Copper, Manganese and Iron. Those individuals responsible for dyeing must know the potential metals levels in process water. These metal ions may be contributed by dyes and/or chemicals used in processing or even from other sources if several water streams are fed into the wastewater treatment plant.

Table 45 shows that dyeings on samples A and B on nylon, and C and D on polyester, were made using water produced during two early runs of the MPP coagulation/settling/filtration unit when color was 125 and 25 Pt-Co color units, respectively. The nylon scavenged color efficiently as expected; whiteness compared to the control dyeing showed about as much color scavenged by the nylon at 25 Pt-Co units of color as when 125 Pt-Co units of color was in the effluent from that unit. This suggests that the amount of color present may well be secondary to what dyes or other chromophoric compounds constitute the color. Polyester scavenged no color in sample D when the pilot plant water contained only 25 Pt-Co units of color. However, when effluent color was increased to 125 Pt-Co units, a noticeable lessening of whiteness was recorded which indicated that some color had indeed been scavenged by the polyester.

It was significant that the amount of color for the two runs, through only the MPP unit, was only slightly different in the influent, but drastically different in the effluent. This is attributed to more water soluble dyes present in the first run which were not coagulated and removed. The pilot plant run on 1/14/76 (See Table 46) was made without alum. Color reduction in the MPP pilot coagulation/settling/filtration unit apparently resulted from physical removal only because no chemicals were used. However, the pilot plant run made the following day was made with greater than 250 mg/l alum as the primary coagulant. This obviously had a very significant effect in that color was reduced by eighty-four percent. The fact that the average Pt-Co units of color varied from 400 units on one day to 300 units on the following day should be noted. Despite these differences, full scale wastewater treatment plant effluent for both these two days were measured at 150 Pt-Co units of color. The most logical explanation is that the mixture of dyes contributing to this color were different on these two days. These two experiments, shown in Table 46, of by-passing the 5-column train in the pilot plant were considered sufficient to confirm that advanced wastewater treatment beyond chemical coagulation, settling and filtration would be required to produce a pilot plant effluent capable of being used in dyeing all fibers satisfactorily.

TABLE 46. COLOR REMOVAL - COAGULATION/SETTLING/FILTRATION

	Full Scale Wastewater Treatment Plant			Pilot Plant	
				MPP Unit Only	
Date	Influent	Biologically Treated Plus Chlorination	Multimedia Filter Final Effluent	Influent	Effluent
1/14/76	400	200	150	150	125
1/15/76	300	175	150	150	25

LABORATORY TEST DYEINGS

A large number of one-liter laboratory dyeings were made on nylon, acetate, triacetate and polyester substrates, using many of the dyes listed for that substrate in Table 47. In order to obtain satisfactory dyeings in a full range of shades including white and pastel shades, particularly on nylon and triacetate fibers, it was necessary to provide an essentially colorless treated wastewater for dyeing. A higher color level could be tolerated when dyeing polyester; however, care should be taken to keep this level of color

TABLE 47. LABORATORY DYE/FIBER TEST COMBINATIONS

Fibers	Dyestuffs
1. Nylon 66, Antistatic Additive	1. Fluorescent brighteners 191 & 59
2. Nylon 6	2. Disperse Blue 3
	3. Disperse Yellow 3
	4. Disperse Red 91
	5. Nylanthrene Blue GLF
	6. Nylanthrene Yellow WGL
	7. Nylanthrene Red ACD
	8. Acid Blue 78
	9. Acid Red 99
	10. Acid Red 4
	11. Acid Yellow 7
	12. Direct Blue 86
	13. Acid Red 52
	14. Acid Red 289
3. Secondary Acetate	1. Fluorescent Brightener 135 and Leucophor SF
4. Triacetate	2. Disperse Blue 27
	3. Disperse Blue 7
	4. Disperse Red 91
	5. Disperse Yellow 86
	6. Disperse Red 117
	7. Disperse Yellow 42
	8. Disperse Blue 87
	9. Disperse Yellow 82
*Secondary Acetate Only	*10. Basic Red 15
	*11. Basic Blue 3
5. Polyester (Dacron T/56, T/92 Blend)	1. Fluorescent Brightener 135
	2. Disperse Blue 56
	3. Disperse Blue 87
	4. Disperse Yellow 64
	5. Eastman Poly Yellow 7GT
	6. Disperse Red 60
	7. Disperse Red 4
	8. Basic Blue 71
	9. Basic Yellow 54
	10. Basic Red 29
6. Nylon T/66 (Automotive)	1. Acid Black 131
	2. Acid Black 132
	3. Acid Orange 80
	4. Acid Yellow 129
	5. Acid Red 213
	6. Acid Red 263
	7. Acid Green 40
	8. Acid Blue 62

low, preferably below 20 Pt-Co units. The treated water should also have a very low metal ion content, preferably less than 0.1 mg/l of any single metal.

Laboratory dyeings were made on 20-gram swatches of fabric in a total liquor of one-liter for a 50:1 liquor to fabric weight ratio. Preliminary dyeings were made using effluent from the pilot plant to determine whether water quality was sufficiently good to consider larger scale dyeings. The dyes and chemicals used were obtained from manufacturing plant stock and solutions were prepared according to standard dye laboratory practices in accordance with manufacturer's and/or seller's recommendations. Laboratory tap water, taken from processing water used in dyeing and finishing in the manufacturing plant, was used for all chemical and dye stock solution preparations.

These 20-gram swatch dyeings, both control and exploratory, were all made on a dye laboratory steam table at approximatly (99°C) 210°F for one hour, unless otherwise specified. This time included the approximately ten minutes required for the bath to reach the desired process temperature. Swatches were rinsed in laboratory tap water after dyeing.

Chemicals used were selected to be compatible with the type of dye and fiber/fabric to be dyed. Dispersed dyes were applied to acetate fiber/fabric with the use of 0.25 grams per liter of the sodium salt of ethylenediaminetetraacetic acid (EDTA) sequesterant. 0.2 grams per liter of a blended anionic/nonionic scouring/dyeing assistant, and 1.0 gram per liter of monosodium phosphate to aid in scouring, without adversely affecting exhaustion or any color property.

Disperse dyes were applied to nylon using 0.25 grams per liter of EDTA, 0.2 grams per liter of a blended anionic/nonionic, scouring/dyeing assistant and 1.0 gram per liter of sodium tripolyphosphate to aid in scouring and to improve levelling (uniform uptake by the fabric) of the dye.

Neutral dyeing acid dyes were applied to nylon using 0.25 grams per liter of an anionic dyeing assistant, with affinity for the fiber under acid conditions, 0.20 grams per liter of a very slightly cationic dyeing assistant with some affinity for the anionic acid dye (this weak bond would be broken by time and increasing temperature to allow the dye to attach itself chemically to cationic dye sites on the fiber); 1.0 gram per liter of monosodium phosphate which gave a pH of approximately 6-6.5 to promote exhaustion of the dye at approximately 99°C (210°F). No sequestering agent was used in making these dyeings because any slight amount of hardness contributed by dye or chemical would have a positive effect on dye exhaustion and the dyes used exhibited no extreme metal sensitivity. Experience has shown that the amount of metal ions normally present in the dyeing bath at this location has no serious effect on the shade of the dyeing.

Basic dyes, often referred to as cationic dyes because they are positively charged, were applied in a strongly acid dyebath at pH 3.0 - 3.5, 99°C (210°F) for one hour. This dyebath also contained three grams per liter of a dye carrier specific for exhaustion of this cationic dye onto copolymer polyester, while reducing the tendency to stain homopolymer polyester. In addition, six grams per liter of sodium sulfate (Glauber's salt) was added to prevent degradation of the copolymer polyester in this particular fabric blend. Basic dyes were applied to acetate at pH 5 using one gram per liter of carrier at 99°C (210°F) for one hour.

Premetallized dyes were applied to nylon using 0.4 grams per liter of an anionic levelling agent, 0.02 grams per liter of copper sulfate, at pH 5-5.5 (using citric acid for pH adjustment). Dyeing was carried out for 1.5 hours at 99°C (210°F). In dyeing with premetallized dyes, a sequestering agent was not used. An excess of sequestering agent could break down the dye to metal bond and destroy the high lightfastness of this group of dyes.

Optical brighteners were applied to all fibers using one gram per liter of monosodium phosphate plus 0.2 grams per liter of nonionic surfactant for one hour at 99°C (210°F).

Triacetate used in these dyeings was part of a tricot fabric blend of 80% triacetate/20% nylon. The nylon was so placed in the construction that it was essentially hidden and had no significant effect on the final dyed shade. Dyeings were carried out at 99°C (210°F) on the laboratory steam table using a dyebath containing three grams per liter of a commercially available carrier (butyl benzoate is the active carrier ingredient), 0.2 grams per liter of an anionic/nonionic blended surfactant/dyeing assistant at pH 4-4.5 (pH adjusted with citric acid).

Dyeings were made on polyester in a closed pressurized container, holding 0.5 liters of dyebath so that the liquor to fabric weight ratio was 25:1 instead of 50:1 as in other small laboratory dyeings. One-hour dyeings were done at 110°C (230°F); however, at a 3°C/minute (5°F/minute) rate of temperature rise and rate of cooling, the time of actual dyeing was slightly longer than one hour. The dyebaths contained three grams per liter of perchloroethylene carrier, 0.3 grams per liter of a fatty ester lubricating agent and 0.25 grams per liter of sequesterant, at pH 4.5-5 (pH adjusted with citric acid).

Confirmatory dyeings were made using a laboratory-size pressure beam dyeing machine. Approximately 400 grams of fabric (sixteen inches wide) was wrapped onto a perforated stainless steel cylinder and inserted in the laboratory dye machine. Approximately eight liters of manufacturing process water per dyeing for control dyeings and water from the pilot plant effluent for evaluation dyeings were used to fill the machine. Water was pumped into one end of the perforated cylinder, through the perforations, and out through the fabric wrapping; flow was always in one direction, from the inside to the outside. The dyebath was charged with dyes and chemicals prepared as described previously for the small laboratory swatch dyeings. The rate of temperature rise was approximately 3°C per minute (5°F per minute) and was raised by steam heat exchange through tubes located in the bottom of the beam dye machine. Rate of cooling was approximately 7°C (13°F) per minute because cooling was carried out by overflow cooling the dyebath by the slow addition of manufacturing process water.

The dyeing temperature was 99°C (210°F) for nylon, acetate and triacetate. For polyester dyeing, a stainless steel lid was bolted onto the top of the beam dye machine and temperature was raised to 110°C (230°F). The rate of temperature rise and cooling was the same as for those dyeings made at 99°C (210°F). Reasonably good correlation of shade was obtained between the ten or twenty gram swatch, made in 0.5 or 1.0 liter of dyebath, with the 400 gram dyeing, made in eight liters of water in the pressure beam dyeing machine.

The individual laboratory dyeings for each dye/fiber combination were made and compared in light and medium bright shades. There was no deleterious effect on the color of the dyeings made from the highest quality pilot plant effluent. When the pilot plant effluent was essentially colorless, high quality dyeings were obtained. Spectrophotometric evaluations confirmed the visual ratings of acceptability. These instrumental readings were made using a "Spectroscan" spectrophotometer integrated into an Applied Color System, Inc. ACS-500 computer system.

COLORFASTNESS OF FABRICS DYED USING PILOT PLANT TREATED WASTEWATER

Based on these experiments, there was no detrimental effect on colorfastness to washing, sublimation, crocking (rubbing), perspiration, oxides of Nitrogen fading, ozone fading, or lightfastness (carbon arc), when dyeings were made using essentially colorless pilot plant effluent for dyeing. These evaluations included tests made on selected dyeings of dispersed dyes on triacetate, basic (cationic) dyes on copolymer polyester, acid dyes on nylon, a disperse blue dye on a design fabric made from a blend of both homopolymer and copolymer polyester, premetallized dyes on nylon, a direct blue on nylon, dispersed dyes on polyester, an optical brightener on polyester, and a different optical brightener on nylon. The dyes used in this particular evaluation with the exception of the direct dye on nylon, and a fluorescent disperse yellow on copolymer polyester, were all expected to exhibit good colorfastness. There were no unexpected developments in this series of evaluations.

SUMMARY

Laboratory dyeings were made using effluent from the complete pilot treatment plant each time the effluent quality was essentially colorless. Consequently, dyeings were made over a number of days and water from several pilot runs was used. These variables, notwithstanding color of the swatches dyed in pilot plant effluent, matched the color on the control dyeings. There was every indication that similar satisfactory dyeings could have been made using fullsized production equipment and that the dyed fabric would have been shipped as first quality product.

These laboratory dyeings confirmed that the pilot wastewater treatment plant, operated in its entirety, did produce wastewater of sufficiently high quality to be reused in dyeing fabrics of man-made fibers of nylon, acetate, triacetate and polyester. The dyeings made from this treated wastewater were equal in quality, color, brightness and colorfastness to parallel dyeings made using control water from manufacturing process storage.

Residual color in the wastewater normally discharged to a receiving stream proved to be the most difficult parameter to remove, as had been anticipated. A satisfactory treatment scheme was developed to remove this residual color and with it almost all BOD_5, COD, TOC, metals, suspended solids, etc. The system was also capable of effectively removing TKN. Wastewater was sufficiently treated to be reused in several dyeing processes as the vehicle for dyeing man-made fiber fabrics satisfactorily.

SECTION 9

PRELIMINARY DESIGN OF A ONE MILLION GALLON PER DAY TREATMENT PLANT

The application of pilot technology, as described in Section 7, to full-scale operation was considered technically achievable. Current economic constraints at this particular manufacturing location made a full-scale advanced wastewater treatment plant unattractive economically. However, there are those who may wish to apply this technology to produce water of reusable quality in manufacturing.

WASTEWATER TREATMENT PLANT DESIGN FLOW SEQUENCE

The preliminary design of a 1 MGD wastewater treatment plant has been prepared to produce an effluent capable of being used as process water in a dyeing and finishing plant. This wastewater treatment plant would include a nine hundred gallon-per-minute reactor/clarifier with provision for the addition of alum and polyelectrolyte coagulant aids. The supernatant would be transferred to a 50,000 gallon capacity clear well; heavy chemical sludge would be sent to a holding basin for further treatment. Transfer pumps would then transfer up to 1,642 gpm from the clear well to three dual media filters, (anthracite and sand), ten feet in diameter. Table 48 and Figure 8 present the necessary preliminary design data. The dual media filters' function is to remove coagulant.

The net effluent flow of 1210 gpm from the dual media filter would then be treated by three nine-foot diameter activated carbon filters for color and organic removals. Three eight-foot diameter organic traps would then receive a net flow of one thousand gallons per minute for additional organic removal. Three cation exchangers, eight feet-six inches in diameter, would remove multivalent metals and other positively charged ions such as residual cationic dyes. The one thousand gallons per minute effluent from the cation exchangers would flow to a degasifier, functioning with a 2800 cfm air flow to dislodge

TABLE 48. DESIGN DATA FOR 1 MGD SCALE UP OF PILOT PLANT

EQUIPMENT	REACTOR/ CLARIFIER (R/C)	DUAL MEDIA FILTERS (DMF)	ACTIVATED CARBON FILTERS (GAC)	ORGANIC TRAP (OT)	CATION EXCHANGER (CE)	AERATOR W/CLEARWELL (AC)	ANION EXCHANGER (AE)
No. of Units	1	3	3	3	3	1	3
Maximum Influent (GPM)	900 Avg.	1642	1210	1000	1000	1000	1000
Max. Effluent/ Unit (GPM)	1642	500	500	500	333	1000	350
Max. Effluent	1642	1000	1175	1000	1000	1000	700
Media	--	Anthracite .60-.80 mm Filter Sand .45-.50 mm	20 x 50 Mesh Activated Carbon	Dowex 11	IR 120	--	IR 47
Volume of Media/ Unit (Cu.Ft.)	--	157 157	190	175	434	--	245
Depth of Media (Inches)	--	24 24	36	42	92	--	60
Diameter of Column (Ft.)	--	10	9	8	8.5	--	8
Height of Column (Ft.)	--	6.0	5.0	8.0	14.5	--	9.75
Chemical Feeds	Alum Polyelectrolyte	-	-	-	-	--	-
Regeration or Backwash	--	Backwash Only	Backwash Only	Backwash & Regeneration	Backwash & Regeneration	--	Backwash & Regeneration
Regenerant	--	-	-	NaCl	A & B H_2SO_4	--	Sodium Carbonate
% Solution Regenerant	--	-	-	5%	(A)2, (B)4	--	3%
Lbs. Regenerant/ Regeneration	--	-	-	525	2170	--	1225
Backwash/Regeneration Waste GPD	5000*	30,000	10,000	40,000	75,000	--	75,000

*Sludge wasting rate

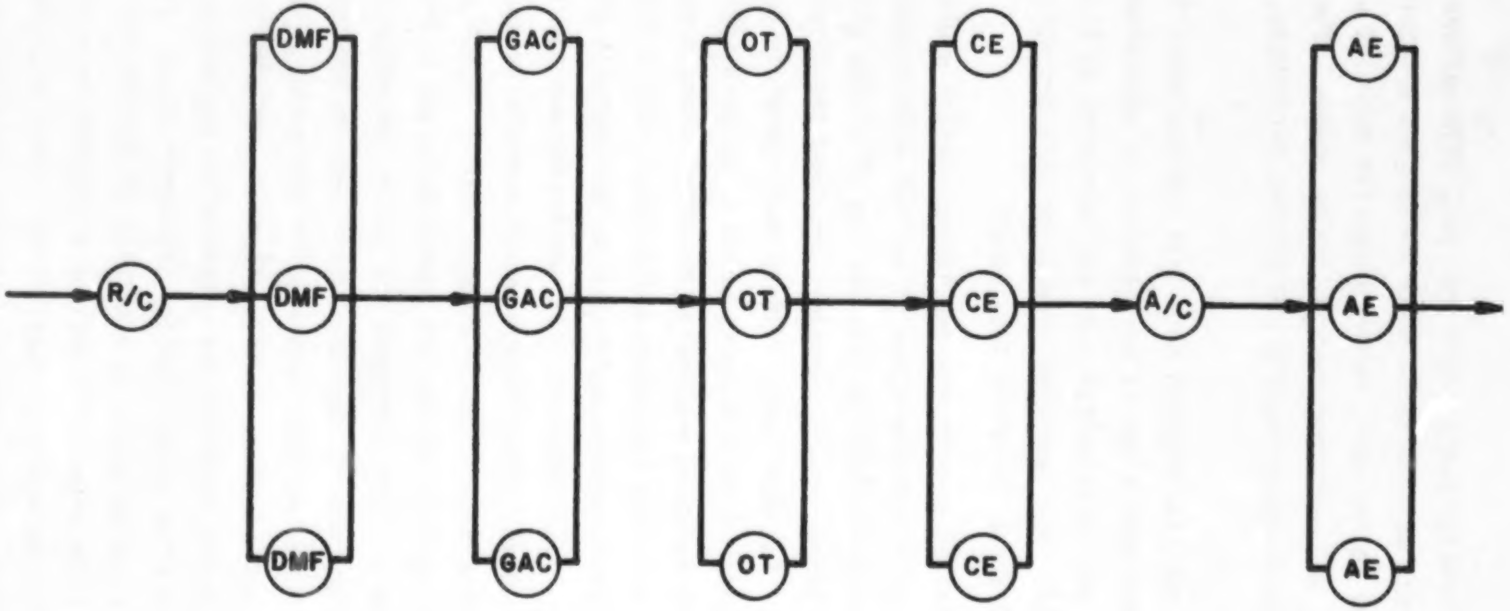

R/C
DMF
DMF
DMF
GAC
GAC
GAC
OT
OT
OT
CE
CE
CE
A/C
AE
AE
AE

Figure 8. Process flow schematic - 1 mgd plant.

entrapped CO_2. Transfer pumps would then pump 1000 gallons per minute from the degasifier clear well to three anion exchangers eight feet in diameter. The anion exchange resins would remove excessive nutrient anions and any remaining, soluble, anion-charged residual color bodies. The above system would produce a net flow of approximately 700 gallons per minute, or 1,000,000 gallons per day.

The cost of the construction materials and equipment for the 1,000,000 gallon per day treatment plant is estimated to be approximately $1,500,000. The construction and installation cost was estimated at $1,500,000 for a total cost of $3,000,000. The land area needed for this project was estimated to be approximately 3.5 acres including the lagoon.

The major difficulty with the preliminary design would be the handling of the wastewater from the regeneration of various unit processes. The reactor/clarifier would generate 5000 gallons per day of sludge which could be diverted to an existing digester or concentrator, provided the existing facility was adequate in size. The dual media filters would generate up to 30,000 gallons per day of wastewater from backwashes which could be diverted to the equalization lagoon of the existing wastewater treatment plant provided plant hydraulic flow through the existing equipment would permit such a flow routing. The effect of the existing system would have to be carefully evaluated prior to rerouting this flow. The nature of this wastewater and the 10,000 gallons per day from the activated carbon filters would probably be such that it would be advantageous to discharge it in to an equalization lagoon prior to any treatment. The 40,000 gallons per day of regeneration waste from the organic trap, the 75,000 gallons per day each from the cation and anion exchangers; would generate 190,000 gallons per day that would require separate disposal. The possibilities of handling this regeneration wastewater with evaporators or reverse osmosis are solutions to this disposal problem. The effluent from a reverse osmosis system treating the regeneration wastewater could be diverted back to the one million gallon per day treatment plant. Evaporators alone or a reverse osmosis system would be expensive to install and operate. The further treatment of the regenerant must be evaluated, on a site-specific basis, for both technical and economic feasibility. Cost estimates for treating the regenerant wastewater were not made. Another important consideration with this type of wastewater treatment system is the land area required for installation. This consideration of land requirements/availability is site-specific and must be evaluated on a case by case basis.